5.0 IN-RIVER DISTRIBUTION OF CONTAMINATION

This section presents information on the distribution of contamination in the river environment based on data collected through July 19, 2010 and focuses on the in-river contaminant distribution in and immediately adjacent to the Study Area, as well as up- and down-river of the Study Area. Section 5.1 presents the criteria for selection of contaminants for discussion and use in the RI; Section 5.2 discusses the in-river distribution of contaminants in bedded sediments; Section 5.3 discusses mobile sediment (as measured in sediment traps); Section 5.4 discusses the in-river distribution of contaminants in surface water; Section 5.5 discusses the distribution of contaminants in TZW and groundwater seeps; and Section 5.6 discusses the distribution of contaminants in biota.

The discussions in the following subsections focus on distribution of contamination as orders of magnitude of detected values (e.g., <1, 1–10, 10–100, 100–1,000, etc.). Depending on the medium examined, the discussion of contaminant distribution is supported by a variety of tabular and graphical materials: 1) maps showing the extent of each contaminant's distribution, 2) summary statistics tables, 3) scatter-plot graphs depicting chemical concentrations by river mile, and 4) histogram plots for comparing values. The summary statistics tables present frequency of detection; minimum, maximum, mean, median, and 95th percentile; and the station locations of the maximum values. Summary statistics are calculated using only detected values as well as combined detect and non-detect values. These statistics have been compiled separately for the RI Study Area Reach (RM 1.9–11.8, exclusive of the Multnomah Channel), the Downtown Reach (RM 11.8–15.3), the Upriver Reach (RM 15.3–28.4), and the Downstream Reach (RM 0–1.9) [refer to Map 5.0-1]. Summary statistics for sediments include both point samples and beach composite samples to provide a general understanding of contaminant concentration distributions.

Where specific sample results are cited in the text (i.e., the concentration of a sample, median and 95th percentile values), qualifiers and descriptors associated with that result are also cited, with one exception. The descriptor "T" is not cited as it generally indicates that the result was mathematically derived through summing multiple results (e.g., total PCB congeners equal the sum of the PCB congener results).[1] The "T" descriptor may also indicate that a result is an average of multiple results for a single analyte (e.g., field replicates) or that a result was selected for reporting in preference to other available results (e.g., for parameters reported by multiple methods). The descriptor "A" indicates a total value is based on an incomplete number of analytes (e.g., seven of the nine PCB Aroclors) and is cited with the results.

Similarly, the following laboratory qualifiers are also cited with the results:

J – The associated numerical value is an estimated quantity.

[1] The "T" qualifier appears on some maps.

N – Presumptive evidence of presence of organic compound; identification of the compound is not definitive. The N qualifier is used in combination with the J qualifier.

U – The material was analyzed for, but was not detected. The associated numerical value is the sample quantitation limit.

In certain cases, concentrations of closely-related analytes were added together to create a group sum. When calculating group concentrations for this in-river contaminant distribution evaluation, a value of zero was used for non-detected concentrations on an individual sample basis. 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) toxic equivalent concentration (TEQ) values for dioxin-like PCB congeners and PCDD/Fs were calculated using WHO 2005 toxicity equivalency factors (TEFs) for mammals[2] (Van den Berg et al. 2006). Benzo(a)pyrene (BaP) equivalent (BaPEq) values used to represent carcinogenic PAHs (cPAHs) were calculated using PEFs provided in EPA (1993b). Further information on summing methods is provided in Appendix A.

5.1 SELECTION OF INDICATOR CONTAMINANTS

COIs are contaminants expected to be present at a site based on a review of site information. Numerous chemical parameters were identified for the Study Area from the site assessment and were subsequently analyzed for and detected in various sampled media. Summary statistics for all COIs are presented by media for each river reach in Appendix D. Table 5.1-1 presents the COIs detected in the various media (sediment, water and biota) of the river.

Due to the large number of COIs detected at the site in various media, the RI will focus on a subset of the contaminants—designated as indicator contaminants—to facilitate a clear and practical presentation of the distribution of contamination in the Study Area. It should be noted that additional contaminants beyond the indicator contaminants presented in this section are present at the site at concentrations that may pose unacceptable risk to human health and the environment, and limiting the discussion of contaminants in this section in no way limits the contaminants that will be considered in the FS or cleanup decisions made by EPA.

Indicator contaminants were identified using a screening process (Table 5.1-2) that first compared the detected COIs at the site (Table 5.1-1) with those contaminants posing unacceptable risk to human health and the environment and then considered the following factors:

- Frequency of detection—Contaminants with a frequency of detection less than 20 percent were not selected.

[2] The World Health Organization (WHO) has provided a list of 12 dioxin-like congeners: PCB-77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169, and 189.

- Cross media comparisons—Contaminants that would allow comparisons across media were selected.
- Collocation of contaminants—Several contaminants were selected to represent other contaminants due to collocation of the contaminants (for example, arsenic, chromium, copper, and zinc were selected to represent other metals).
- Widespread sources—Certain other contaminants with widespread sources in the harbor (e.g., metals, PAHs, and PCBs) were selected.
- Grouped contaminants—Some contaminants were grouped as one contaminant. Contaminants that were grouped include PCBs, PCDD/Fs, DDx, and PAHs.
- Low exceedance of risk—Several contaminants did not contribute significantly to risk estimates (hazard quotient [HQ] <10 or risk at 10^{-6}) and were not selected.

The first screen identified 35 contaminants in the Study Area. An additional screen identified a subset of 13 indicator contaminants, which are the focus of further discussion in the main text of the RI. Although not discussed further in the main RI report, summary statistic tables, maps, and figures by media are presented in Appendix D for the 21 contaminants that were not identified as indicator contaminants.

Table 5.1-2 identifies the 13 indicator contaminants selected by this process for further discussion in the RI. Contaminants that were screened due to collocation were based either on one form of a contaminant representing another or on a correlation plot of the rank and location of the data sets. The basis for each contaminant screening due to collocation is presented in Table 5.1-3 and Figures 5.1-1 through 5.1-5.

Data presentations identical to those provided in the following sections are also provided for physical parameters and other COIs in Appendix D; however, there is no discussion or interpretation of the information. Appendix D also provides discussions of patterns and trends in the constituent chemicals of grouped analytes (e.g., PCBs, PCDD/Fs, PAHs, DDx).

5.2 INDICATOR CONTAMINANTS IN BEDDED SEDIMENT

This section summarizes the surface and subsurface sediment data collected in the Upriver Reach, Downtown Reach, Study Area Reach, and Downstream Reach. The locations of all surface and subsurface sediment samples in the RI data set are shown on Maps 2.1-15 and 2.1-17. The discussion of each contaminant focuses primarily on the following items:

- A description of the data set for each contaminant, including sample counts, concentration range, and frequency of detection.
- A discussion of the surface and subsurface concentration distributions in the Upriver Reach, Downtown Reach, RI Study Area Reach, and Downstream Reach. The RI Study Area Reach is organized by eastern nearshore, western

nearshore, and navigation channel subareas (Map 5.2-1) and distributions are discussed within river mile reaches and hydrodynamic reaches (see discussion in Section 3).

- A discussion of the vertical trends in sediment concentrations and the relationship of subsurface sediment to surface sediment concentrations.

The sediment chemistry distributions are depicted in three graphical formats:

1. Surface plan-view concentration maps and subsurface core concentration maps
2. Scatter-plot graphs of surface and subsurface sediment (RM 0.8-12.2)
3. Histograms comparing mean surface and subsurface concentrations by river mile (RM 0–11.8).

Core plots showing a higher level of detail have been produced for the following indicator contaminants:

- Total PCBs
- Total DDx
- TCDD TEQ
- Total PAHs.

Additionally, more detailed core plots were developed for total cPAHs and are presented in Appendix D1.2. More detailed core plot maps were developed for these five contaminants because they are more prevalent throughout the Study Area and based on their relative contribution to risk in the baseline risk evaluations (Appendices F and G).

Surface Chemistry Maps: The plan-view concentration maps present all surface sample data using color-coded dots that correspond to a concentration scale for that particular chemical. The concentration ranges (or intervals) used in color-coding the chemical data shown on the maps were based on the frequency distributions (i.e., natural breaks), or as negotiated between EPA and LWG, in the data set for these contaminants and have no environmental significance. Non-detected concentrations are differentiated from detected concentrations on the surface maps by a dot in the center of the sample symbol ⊙. The maps include data points from locations that were dredged or capped subsequent to the collection of the sample(s) shown by a circle centered around the sample symbol ◎.[3,4] Data from these areas are presented to show spatial

[3] For example, all data shown for locations *within the capped area* at the McCormick and Baxter site (see Maps 2.1-15i and 2.1-17i) are from surveys completed between 1999 and 2002, prior to capping. These data are shown on the surface and subsurface core plan-view maps and included in the map histograms; however, they are not included in the other sediment data presentations (i.e., scatter plots and histograms).

patterns of chemicals from a historical, pre-dredge perspective. In addition, the surface maps include histograms showing the distributions and frequencies of the detected and non-detected results. Data from all samples shown on the maps are included in the histograms.

Subsurface Core Maps: The core maps show the distribution of contaminants with depth at each of the subsurface sediment sampling stations (these maps also include the surface sample data). Inset maps for densely sampled core areas are provided in most cases. In these maps, the actual core station is marked with a triangle △. The core segment divisions displayed on the maps are scaled to the thickness of each sample interval. Note that these maps do include cores from locations that were subsequently dredged or capped, as indicated on the maps. Cores taken post-dredging are also included on the maps.

Scatter Plots: Scatter plots present the distribution of detected contaminants in surface and subsurface sediment per river mile. The data are presented in a log scale (by order of magnitude) to facilitate in the discussion on distribution and to fit all the data onto one plot due to the vast range in concentrations detected. To aid in differentiating potential concentration trends in the Study Area, the data in these plots are further separated into eastern nearshore, western nearshore, and navigation channel stations as defined by the federal navigation channel boundary (Map 5.2-1). Data collected in Multnomah Channel are presented with the western shore data and are identified using a different symbol. Likewise, data collected in Swan Island Lagoon are presented with the eastern shore data and identified with a unique symbol. Unlike the plan-view maps, the scatter plots do *not* include data for samples from locations that have been subsequently dredged or capped.

Histograms: The histograms compare the average surface and subsurface sediment chemical concentrations for the indicator contaminants on a subarea basis. The y-axis in the plots is centered on a value of 0, which represents the vertical horizon (i.e., 40 cm bml) between the surface and subsurface samples. Bars extending downward from the y-axis depict the subsurface mean values. Bars extending upward show the surface sediment means. Subareas included east, navigation channel, and west zones for each river mile in the Study Area, as well as Multnomah Channel and Swan Island Lagoon. Mean concentrations were also calculated for each zone in the entire Study Area (see leftmost column in each figure).

These histograms are useful in providing a visual summary of spatially averaged surface/subsurface trends throughout the Study Area. However, some caution is needed in interpreting the trends due to the biased nature of the RI sampling program (i.e., subsurface core samples were generally focused on known areas of contamination, whereas surface samples were distributed more widely). Further, highly contaminated

[4] Surface interval sample locations G088, G087, and G091 collected in 2004 in the International Terminals Slip were dredged subsequent to sampling. These locations were resampled in 2005 at C088, C087, and C091.

areas may not necessarily be contained within a specific river mile, but rather partially overlap two adjacent river miles. Consequently, these histograms should be examined in conjunction with the subsurface core maps in evaluating surface to subsurface trends for a specific contaminant and subarea. This is particularly true for the relatively low density PCDD/F data.

5.2.1 Sediment Data Set

The sediment RI data set is composed of all Category 1 LWG and non-LWG data (refer to Appendix D1.3, Table D1.3-1) collected within the Downstream Reach (RM 0 to 1.9), the RI Study Area Reach (RM 1.9 to 11.8), the Downtown Reach (RM 11.8 to 15.3), and the Upriver Reach (RM 15.3 to 28.4), from May 1997 to July 2010. The surface sediment data set includes all samples with intervals starting at 0 cm and extending to depths ranging to 40 cm bml. The subsurface data set includes all samples collected at depths greater than 40 cm bml. The Upriver Reach is dynamic and the channel is coarse-grained with finer-grained sediments generally restricted to small off-channel areas (Maps 2.1-2a-b); thus, most of the main channel above RM 20 could not be sampled with a grab sampler because the river bed is cobbled or hard.

Summary statistics for indicator contaminants, percent fines, and TOC in the surface and subsurface sediment samples for the entire RI Study Area Reach are presented in Tables 5.2-1 and 5.2-2. The data from the RI Study Area were segregated into the eastern nearshore, navigation channel, and western nearshore and are presented by river mile in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. These summary statistics do *not* include results from locations that were dredged or capped subsequent to sample collection. The specific surface and subsurface samples excluded from the summary statistics are listed in Appendix D1.3, Table D1.3-32. However, post-dredged sediment samples are included in the summary statistics. Tables 5.2-9 and 5.2-10 present the Study Area indicator contaminant data as orders of magnitude (e.g., <1, 1–10, 10–100, 100–1,000, etc.) for only detected values and for combined detected and non-detected values, respectively. Similar summary statistics and order of magnitude data are presented for the Upriver Reach in Tables 5.2-11 through 5.2-14, for the Downtown Reach in Tables 5.2-15 through 5.2-18, and for the Downstream Reach in Tables 5.2-19 through 5.2-22.

5.2.2 Total PCBs in Surface and Subsurface Sediment

The distribution of total PCBs concentrations at each surface sediment sampling station throughout the Study Area is depicted on Map 5.2-2; concentrations with depth at subsurface stations are depicted in detail on Maps 5.2-3a–hh. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented.

Scatter plots of the total PCBs data set for surface and subsurface sediment in the Study Area are presented on Figures 5.2-1 and 5.2-2, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-1).

Summary statistics for total PCBs in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present the total PCBs data as orders of magnitude (e.g., <1, 1–10, 10–100, 100–1,000, etc.) for only detected values and for combined detected and non-detected values. Finally, a histogram of average surface and subsurface sediment values by river mile and for the entire Study Area is presented in Figure 5.2-3.

Data sets for the Upriver Reach, Downtown Reach, and Downstream Reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown Reach surface sediment samples are presented in Map 5.2-4. Summary statistics for surface and subsurface sediment within the Upriver Reach are shown in Tables 5.2-11 and 5.2-12; the number of data points by order of magnitude is provided in Tables 5.2-13 (detects only) and 5.2-14 (detects and non-detects). Summary statistics for surface and subsurface sediment within the Downtown Reach are shown in Tables 5.2-15 and 5.2-16; the number of data points by order of magnitude is provided in Tables 5.2-17 (detects only) and 5.2-18 (detects and non-detects). Summary statistics for surface and subsurface sediment within the Downstream Reach are shown in Tables 5.2-19 and 5.2-20; the number of data points by order of magnitude is provided in Tables 5.2-21 (detects only) and 5.2-22 (detects and non-detects).

5.2.2.1 Total PCBs Data Set

The surface and subsurface data set includes PCBs analyzed for both Aroclors and congeners. For the purpose of sediment characterization, total PCB congener concentrations represent the sum of detected congener concentrations in a sample. In cases where no congeners were detected, the single highest detection limit of all congeners analyzed is used to represent the total value. Similarly, total PCB Aroclor values reflect the sum of detected Aroclors in a sample.

The relationship between total PCB congener and total Aroclor concentrations is discussed in detail in Appendix D1.4. The coefficient of determination between same-sample congener and Aroclor totals in surface sediment was $r^2 = 0.761$, and $r^2 = 0.476$ for subsurface sediment. Plots of these regressions are presented in Appendix D1.4. For all data (sediment, sediment trap, and biota), r^2 was 0.70. PCB totals based on congeners and Aroclors did not correspond well for 11 sediment samples; an order of magnitude difference was observed between the total congener and total Aroclor results, as described in Appendix D1.4. The evaluation indicates that total Aroclor data may overpredict total PCB congeners in concentrations below ~750 μg/kg total Aroclors and may underpredict above 750 μg/kg. For this reason, PCB congener data were determined to better represent total PCBs concentrations than Aroclor data, as the congener method is less affected by "weathering," non-PCB interferences, and subjective Aroclor identifications.

In this report, total PCB congener concentrations are given priority over total Aroclor concentrations when total PCB congener data exist for any given sample, based on the greater specificity and accuracy of the laboratory method for congeners. Because measured total PCBs concentrations are fairly comparable between methods in most cases, it is useful to use Aroclor concentrations when no PCB congener data exist, which represent the majority of the samples. Combining the PCB data in this way provides greater spatial and temporal coverage than using congener data alone due to the lack of congener data available.

The summary statistics values shown in Tables 5.2-1 and 5.2-2 for total Aroclors and total PCB congeners indicate overall higher sample concentrations of total PCBs when summing congeners. The higher concentrations measured by summing congeners are not a result of differences in laboratory methodology, but rather are attributable to a more targeted sample selection process, in which samples selected for PCB congener analysis frequently targeted areas known or suspected to have relatively high PCB contamination.

Consequently, the total PCBs data set consists of the result for total PCB congeners for each sample when available, and the result for total Aroclors when no total PCB congener data are available for a particular sampling location. Congener analyses for LWG sediment samples generally included all 209 congeners. [5] Total PCBs concentration data for sediment within the Study Area are available for 1,318 surface and 1,543 subsurface samples. Most of the total PCBs data are based on Aroclor analyses (Tables 5.2-1 and 5.2-2). Maps 5.2-5 and 5.2-6 display the locations of surface and subsurface sediment samples analyzed for PCBs and indicate whether PCB congener data, Aroclor data, or both are available.

5.2.2.2 Total PCBs in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Total PCBs were detected in 42 of 81 surface sediment samples within the Upriver Reach (frequency of detection 52 percent). Detected concentrations ranged from 0.29J to 31 µg/kg (Table 5.2-11). Total PCBs (Tables 5.2-13 and 5.2-14) were at or greater than 10 µg/kg in 4 samples, between 1 and 10 µg/kg in 33 samples, and less than 1 µg/kg in 5 samples. The mean total PCBs concentration in this reach is 4.48 µg/kg.

Downtown Reach (RM 11.8 to 15.3)

Total PCBs were detected in 195 of 265 surface sediment samples within the Downtown Reach (frequency of detection 74 percent). Detected concentrations ranged from 0.798 J to 19,700 µg/kg (Table 5.2-15). Concentrations reported were greater than 10,000 µg/kg in 3 samples, between 1,000 and 10,000 µg/kg in 12 samples, between

[5] The exception is that total Aroclor data were selected to represent total PCBs for Round 2A beach sediment samples because the beach samples were only analyzed for coplanar PCB congeners, which constitute a small fraction of the total PCBs.

100 and 1,000 µg/kg in 51 samples, between 10 and 100 µg/kg in 81 samples, between 1 and 10 µg/kg in 47 samples, and less than 1 µg/kg in 1 sample (Tables 5.2-17 and 5.2-18).

The majority of samples with concentrations greater than 1,000 µg/kg were located along the western shoreline between RM 13.5 and 14.1, which is the location of the Zidell facility. In 2011, a remedial action was conducted at the Zidell facility under DEQ authority. Within the area addressed by the remedial action, total PCBs were detected in 111 surface sediment samples (frequency of detection of 73 percent). Concentrations reported ranged from 1.27 to 19,700 µg/kg, with a mean of 1,320 µg/kg (Table 5.2-15). When the data for the Zidell facility are removed from the Downtown Reach data set (Table 5.2-15), total PCBs concentrations in surface sediment ranged from 0.798 J to 4,200 µg/kg, with a mean of 108 µg/kg.

Study Area Reach (RM 1.9 to 11.8)

Total PCBs were detected in 80 percent of surface sediment samples (1,052 detections) within the Study Area. Concentrations reported ranged from 0.851 J to 35,400 µg/kg (Table 5.2-1), and varied throughout the Study Area (Figure 5.2-1). This information is presented on Map 5.2-2 (total PCBs concentrations exceeding 1,000 µg/kg are indicated in red). Several prominent concentration peaks, defined as greater than 1,000 µg/kg, are present in the eastern nearshore zone: RM 1.9–4, 6–7, Swan Island Lagoon, and RM 11–11.8 (Figure 5.2-1). Mean total PCB concentrations in these areas are: 663 µg/kg at RM 1.9–3, 369 µg/kg at RM 3–4; 223 µg/kg at RM 6–7, 373 µg/kg in Swan Island Lagoon; and 495 µg/kg at RM 11–11.8 (Table 5.2-3).

The highest total PCBs concentrations along the western side of the river are found in the western nearshore zone from RM 8–10; including the highest detected surface concentration (35,400 µg/kg) at Station G453 (RM 8.8). Mean total PCBs concentrations in this area are 978 µg/kg at RM 8–9 and 341 µg/kg at RM 9–10 (Table 5.2-7).

The highest concentrations found in the navigation channel zone are at RM 11–11.8, which appears to be an extension of the contamination noted along the eastern nearshore area (Map 5.2-2). The maximum detected concentration in this area is 5,900 µg/kg, with a mean concentration 292 µg/kg (Table 5.2-5).

Total PCBs concentrations greater than 10,000 µg/kg were found in only two locations: in the western nearshore zone, at RM 8.8 and in Swan Island Lagoon (Tables 5.2-9 and 5.2-10; Maps 5.2-3t,x). Total PCBs concentrations between 1,000 and 10,000 µg/kg were reported in 37 samples, all within the areas described above. Overall, concentrations greater than 1,000 µg/kg account for 4 percent of detected results (39 samples), 19 percent were between 100 and 1,000 µg/kg (203 samples), 59 percent (621 samples) were between 10 and 100 µg/kg, 18 percent (188 samples) were between 1 and 10 µg/kg, and 1 sample was detected at a concentration less than 1 µg/kg (Table 5.2-9).

Downstream Reach (RM 0 to 1.9)

Total PCBs were detected in 16 of 25 surface sediment samples within the Downstream Reach. Concentrations reported ranged from 1.03 J to 410 µg/kg (Table 5.2-19), with a single result greater than 100 µg/kg (Tables 5.2-21 and 5.2-22). Overall, concentrations between 10 and 100 µg/kg accounted for 16 percent of detected results (4 samples), and 44 percent were between 1 and 10 µg/kg (11 samples). The mean total PCBs concentration in this reach is 33.7 µg/kg.

5.2.2.3 Total PCBs in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

Three subsurface sediment samples were analyzed for total PCBs within the Upriver Reach between RM 15.4 and 16. All results were reported as non-detect, with a maximum reporting limit of 11 µg/kg (Table 5.2-12).

Downtown Reach (RM 11.8 to 15.3)

Total PCBs were detected in 59 of 110 subsurface sediment samples within the Downtown Reach. Concentrations reported ranged from 1.4 J to 610 µg/kg (Table 5.2-16) with a mean concentration of 92 µg/kg. Within this reach, 14 percent (15 samples) of the reported results were between 100 and 1,000 µg/kg, 44 percent (31 samples) were between 10 and 100 µg/kg, and 22 percent (13 samples) were between 1 and 10 µg/kg. All detected results were greater 1 µg/kg (Tables 5.2-17 and 5.2-18). Only two subsurface samples were collected from the vicinity of the Zidell facility, and the reported concentrations were 140 µg/kg and 190 µg/kg.

Study Area Reach (RM 1.9 to 11.8)

Total PCBs were detected in 939 subsurface samples within the Study Area (detection frequency of 61 percent), with detected concentrations ranging from 0.00138 J to 36,800 µg/kg (Table 5.2-2). Similar to surface sediment, total PCBs concentrations in the subsurface also varied within the Study Area. Several areas of higher concentrations (greater than 1,000 µg/kg) in the subsurface data are identified in the eastern nearshore zone (Figure 5.2-2, Maps 5.2-3a-hh) from RM 1.9–4, 5–6, Swan Island Lagoon, and RM 11–11.8. Mean concentrations in these areas are 521 µg/kg at RM 1.9–3; 1,530 µg/kg at RM 3–4; 369 µg/kg at RM 5–6; 560 µg/kg in Swan Island Lagoon; and 464 µg/kg at RM 11–11.8 (Table 5.2-4).

An area of high total PCBs concentrations is located in the western nearshore zone from RM 7–10. The highest subsurface concentration of 36,800 µg/kg was reported in the sample from Station C455 at 30–152 cm bml (Map 5.2-3v). Mean total PCBs concentrations in this area are 177 µg/kg at RM 7–8; 931 µg/kg at RM 8–9; and 424 µg/kg at RM 9–10 (Table 5.2-8).

The highest reported concentrations in the navigation channel are at RM 10–11.8. Mean total PCBs concentrations in this area are 443 µg/kg at RM 10–11 and 107 µg/kg at RM 11–11.8 (Table 5.2-6). The higher concentrations at RM 10–11 appear to be associated with the western nearshore area, whereas concentrations at RM 11–11.8 appear to be associated with the eastern nearshore area (Maps 5.2-3cc-hh).

Overall, 6 samples had reported total PCBs concentrations greater than 10,000 µg/kg. These were located in the eastern nearshore zone from RM 3–4E, Swan Island Lagoon, and the western nearshore zone from RM 8–9 (Tables 5.2-9 and 5.2-10; Maps 5.2.3a-hh). An additional 40 samples had reported concentrations between 1,000 and 10,000 µg/kg; all were located within the areas described above. Total PCBs concentrations in subsurface sediment greater than 1,000 µg/kg account for 5 percent of the detected results, 34 percent (319 samples) were between 100 and 1,000 µg/kg, 50 percent were between 10 and 100 µg/kg, 9 percent (88 samples) were between 1 and 10 µg/kg, and 2 percent (20 samples) had reported concentrations less than 1 µg/kg.

Downstream Reach (RM 0 to 1.9)

Total PCBs were reported in 13 of 26 subsurface sediment samples within the Downstream Reach. Concentrations reported ranged from 5 to 250 µg/kg (Table 5.2-20). Three samples had reported concentrations between 100 and 1,000 µg/kg, 62 percent (8 samples) had reported at concentrations between 10 and 100 µg/kg, and two samples had reported concentrations between 1 and 10 µg/kg. The mean total PCBs concentration in this reach is 67 µg/kg (Tables 5.2-21 and 5.2-22).

5.2.2.4 Total PCBs Surface and Subsurface Sediment Relationships

The relationship between surface and subsurface sediment total PCBs concentrations were examined by comparing surface and subsurface concentrations by reach, and also by subareas within the Study Area.

There are insufficient data to compare surface and subsurface concentrations in the Upriver Reach because no attempt was made to characterize subsurface sediments in this reach. This reach is unlikely to have significant subsurface contamination due to its dynamic (i.e., non-depositional) nature. The mean surface sediment concentration in this reach is 4.48 µg/kg. Subsurface samples were non-detect for total PCBs, with a reporting limit of 11 µg/kg.

Within the Downtown Reach, total PCBs concentrations were higher in surface sediment than in subsurface sediment. Mean concentrations are 612 and 92 µg/kg in surface and subsurface sediment, respectively. Median concentrations are 45 and 41 µg/kg in surface and subsurface sediments, respectively.

Total PCBs concentrations are generally greater in subsurface sediments than in surface sediments within the Study Area. The mean surface sediment concentration in the Study Area is 220 µg/kg, and the mean subsurface sediment concentration is 351 µg/kg (Tables 5.2-1 and 5.2-2). Median total PCBs concentrations in surface and subsurface sediment are, respectively, 26.9 and 70.0 µg/kg. Mean concentrations are greater in the nearshore areas than in the navigation channel. Total PCBs concentrations are greater in the eastern nearshore zone than the western nearshore zone, and are generally greater in the subsurface sediment than in surface sediment (Figure 5.2-3).

Subsurface sediment concentrations are greater than surface sediment in the eastern nearshore zone in all river miles zones except from RM 1.9–3, 6–7, 10–11, and 11–11.8. In the western nearshore zone, subsurface sediment concentrations are greater than in surface sediment in all river miles except RM 8–9. The subsurface sediment concentrations in the navigation channel are generally greater than the surface sediment concentrations, except from RM 11–11.8. Areas where subsurface sediment total PCBs concentrations exceed 1,000 µg/kg generally align with the locations where surface sediment concentrations are greater than 1,000 µg/kg (Maps 5.2-3a-hh; Figures 5.2-1, 5.2-2, and 5.2-3). Exceptions occur in the eastern nearshore zone, total PCBs concentrations greater than 1,000 µg/kg in surface sediment are found from RM 6–7 and in subsurface sediment from RM 5–6.

The subsurface sediment concentrations in the Downstream Reach were greater than surface concentrations. The mean total PCBs concentrations are 33.7 and 67 µg/kg in surface and subsurface sediment, respectively. The median total PCBs concentrations are 6.8 and 46 µg/kg in surface and subsurface sediment, respectively.

5.2.3 Total PCDD/Fs and TCDD TEQ in Sediment

Polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are evaluated as total polychlorinated dibenzo dioxins/furans (total PCDD/Fs). The summed total value for total PCDD/Fs represents the summed value of the measured homolog concentrations. The toxicity of dioxins and furans is determined by both the number and the position of the chlorine on the molecule, and appears to be a function of the ability to bind to specific cellular receptors. Because only those congeners having a chlorine in each of the 2, 3, 7, and 8 positions exhibit a toxicological response similar to 2,3,7,8-TCDD and other 2,3,7,8 substituted isomers appear to be slightly to substantially less potent, a TEF is used to calculate a PCDD or PCDF toxicity equivalent concentration by multiplying the individual congener concentrations by its respective toxicity TEF. The TCDD TEQ represents the sum of the individual 2,3,7,8-TCDD equivalent concentrations.

The distribution of total PCDD/Fs and TCDD TEQ concentrations at each surface sampling station throughout the Study Area is depicted on Maps 5.2-7 and 5.2-9, respectively; concentrations with depth at subsurface stations are depicted in Maps 5.2-8a–o and in detail on Maps 5.2-10a-m, respectively.

The complete data set for total PCDD/Fs is plotted on scatter plots presented on Figures 5.2-4 and 5.2-5. Figures 5.2-7 and 5.2-8 present scatter plots of the TCDD TEQ data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigation channel, and western nearshore zones (Map 5.2-1).

Summary statistics for total PCDD/Fs and TCDD TEQ in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present the total PCDD/Fs and TCDD TEQ data as orders of magnitude (e.g., <1, 1–10, 10–100, 100–1,000, etc.) for only detected values and for combined detected and non-detected values. Finally a histogram of average surface and subsurface sediment values for total PCDD/Fs and TCDD TEQ by river mile and for the entire Study Area is presented in Figures 5.2-6 and 5.2-9.

Data sets for the Upriver Reach, Downtown Reach, and Downstream Reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown Reach surface sediment samples are presented on Maps 5.2-11 and 5.2-12. Summary statistics for surface and subsurface sediment within the Upriver Reach are shown in Tables 5.2-11 and 5.2-12; the number of data points by order of magnitude is provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and non-detect). Summary statistics for surface and subsurface sediment within the Downtown Reach are shown in Tables 5.2-15 and 5.2-16; the number of data points by order of magnitude is provided in Tables 5.2-17 (detect only) and 5.2-18 (detect and non-detect). Summary statistics for surface and subsurface sediment with the Downstream Reach are shown in Tables 5.2-19 and 5.2-20; the number of data points by order of magnitude is provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and non-detect).

5.2.3.1 Total PCDD/Fs and TCDD TEQ Data Sets

The number of sediment samples for PCDD/F analysis was based on a biased approach at locations near known or suspected sources. As a result, there are fewer data points for these analytes and the resulting TCDD TEQ data in the RI sediment database than for other chemicals (for example, the PCDD/F data set is approximately one-fifth the size of the PCB and DDx data sets). This is particularly true in areas not proximal to suspected sources, such as the navigation channel.

While the existing PCDD/F data are sufficient for RI purposes, the fewer number of data points limits the level of detail on the extent of the contaminant distribution in some areas and introduces the need for caution in interpreting the surface to subsurface trends shown by the histograms (Figures 5.2-6 and 5.2-9), and in making conclusions regarding the spatial patterns of the composition of total PCDD/Fs and TCDD TEQ in sediment (Sections 5.2.3.2 through 5.2.3.5). Total PCDD/Fs data for sediment within the Study Area are available for 237 surface and 327 subsurface samples; there are 238 surface and 331 subsurface samples in the Study Area sediment TCDD TEQ data set.

5.2.3.2 Total PCDD/Fs in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Total PCDD/Fs were reported in 38 of 39 surface sediment samples within the Upriver Reach (frequency of detection 97 percent). Concentrations range from 2.39 pg/g

(0.00239 µg/kg) to 733 pg/g (Table 5.2-11). Concentrations between 100 and 1,000 pg/g were reported in 12 samples (Tables 5.2-13 and 5.2-14), between 10 and 100 pg/g in 17 samples, and between 1 and 10 pg/g in 9 samples. The mean total PCDD/Fs concentration in this reach is 90 pg/g, and the median is 59 J pg/g.

Downtown Reach (RM 11.8 to 15.3)

Total PCDD/Fs were detected in 62 of 67 surface sediment samples within the Downtown Reach (frequency of detection of 93 percent). Detected concentrations range from 9.45 J to 15,400 J pg/g (Table 5.2-15) with a mean of 1,130 pg/g. As shown on Map 5.2-11, the highest detected concentrations are located along the eastern shoreline. Concentrations greater than 10,000 pg/g were reported in a single sample, between 1,000 and 10,000 pg/g in 17 samples, between 100 and 1,000 pg/g in 26 samples, between 10 and 100 µg/kg in 16 samples, and between 1 and 10 pg/g in 2 samples. This information is presented in Tables 5.2-17 and 5.2-18.

In 2011, a remedial action was taken at the Zidell facility under DEQ authority. Table 5.2-15 presents the data statistics for the Downtown Reach excluding the Zidell data and for the Zidell data removed from the Downtown data set. None of the total PCDD/Fs data was excluded from the Downtown Reach.

Study Area Reach (RM 1.9 to 11.8)

Total PCDD/Fs were detected in all 237 surface sediment samples. Reported concentrations range from 2.48 to 264,000 pg/g (Table 5.2-1); the mean is 2,410 pg/g, and the median is 412 pg/g. Detected concentrations exceeding 2,000 pg/g are indicated in red on Map 5.2-7. Total PCDD/Fs concentrations exceeding 1,000 pg/g are found in the eastern nearshore zone at RM 2–8, Swan Island Lagoon, and at RM 11 (Figure 5.2-4). Mean concentrations (see Table 5.2-3) in these areas are 1,170 pg/g at RM 3–4; 1,640 pg/g at RM 4–5; 1,300 pg/g at RM 5–6; 3,440 pg/g at RM 6–7; 1,510 pg/g at RM 7–8; 3,030 pg/g in Swan Island Lagoon; and 1,670 pg/g at RM 11–11.8E.

Concentrations exceeding 1,000 pg/g are found in the western nearshore zone at RM 6–10 and from RM 4–6. Mean concentrations (see Table 5.2-7) in these locations are 726 pg/g at RM 4–5; 830 pg/g at RM 5–6; 1,730 pg/g at RM 6–7; 15,200 pg/g at RM 7–8; 1,500 pg/g at RM 8–9; and 1,650 pg/g at RM 9–10. The highest surface sediment concentration (264,000 pg/g) in the data set was detected between RM 7–8.

The highest total PCDD/Fs concentrations in the navigation channel zone are located at RM 6–7 and RM 11–11.8. It appears that these concentrations are associated with higher concentrations found in the eastern nearshore zone (Map 5.2-7) rather than reflecting conditions in the navigation channel. The maximum detected concentrations at these locations are 2,260 pg/g at RM 6–7, and 2,020 pg/g at RM 11–11.8. Mean concentrations are 779 pg/g at RM 6–7 and 810 pg/g at RM 11–11.8 (Table 5.2-5).

Total PCDD/Fs concentrations greater than 10,000 pg/g were detected in 7 samples (Tables 5.2-9 and 5.2-10), and 63 detected values were between 1,000 and 10,000 pg/g. Overall, concentrations greater than 1,000 pg/g accounted for 30 percent of the detected results (Map 5.2-7), 56 percent (133 samples) were between 100 and 1,000 pg/g, 13 percent (31 samples) were between 10 and 100 pg/g, and 1 percent (3 samples) were detected at concentrations between 1 and 10 pg/g.

Total PCDD/Fs concentrations greater than 2,000 pg/g (indicated in red on Map 5.2-7) were found at several locations along the eastern and western nearshore zones. Limited surface PCDD/F data are available in the navigation channel, and spatial resolution is somewhat limited. However, of the channel samples that were analyzed, most concentrations were less than 500 pg/g (except as noted above), and a pattern is evident of relatively high concentrations in nearshore areas compared with lower concentrations in the adjacent channel areas.

Downstream Reach (RM 0 to 1.9)

Total PCDD/Fs were detected in all 21 samples within the Downstream Reach. Concentrations reported ranged from 1.56 J to 1,780 J pg/g, with a mean concentration of 232 pg/g (Table 5.2-19). Tables 5.2-21 and 5.2-22 show that there was only 1 data point with a concentrations greater than 1,000 pg/g, 38 percent (8 samples) of the reported concentrations were between 100 and 1,000 pg/g, 52 percent (11 samples) were between 10 and 100 pg/g, and 1 sample was between 1 and 10 pg/g.

5.2.3.3 Total PCDD/Fs in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

Total PCDD/Fs were detected in all three subsurface sediment samples in the Upriver Reach; reported concentrations ranged from 3.59 to 1,090 pg/g (Table 5.2-12), with a mean concentration of 816 pg/g. One sample had a reported concentration between 1,000 and 10,000 pg/g, and the other two results were between 100 and 1,000 pg/g (Tables 5.2-13 and 5.2-14).

Downtown Reach (RM 11.8 to 15.3)

Total PCDD/Fs were detected in 39 of 44 subsurface sediment samples and samples within the Downtown Reach (detection frequency of 89 percent), with detected concentrations ranging from 4.74 to 4,590 J pg/g (Table 5.2-15) and a mean concentration of 1,090 pg/g. Overall, concentrations between 1,000 and 10,000 pg/g were reported in 17 samples, 11 were between 100 and 1,000 pg/g, 8 were between 10 and 100 µg/kg, and 3 were between 1 and 10 pg/g. There were no detected results less than 1 pg/g (Tables 5.2-17 and 5.2-18).

In 2011, a remedial action was taken at the Zidell facility under DEQ authority. Table 5.2-16 presents the data statistics for the Downtown Reach excluding the Zidell data and for the Zidell data removed from the Downtown data set. None of the total PCDD/Fs data was excluded from the Downtown Reach.

Study Area Reach (RM 1.9 to 11.8)

Total PCDD/Fs were detected in 325 of 327 subsurface sediment samples within the Study Area (frequency of detection 99 percent). Reported concentrations ranged from 0.0578 J to 425,000 J pg/g, with a mean concentration of 9,050 pg/g (Table 5.2-2). The distribution of reported concentrations is presented on Figure 5.2-5 and Maps 5.2-8a-o).

Total PCDD/Fs concentrations in subsurface sediment greater than 10,000 pg/g were found in the eastern nearshore zone from RM 7–8 (Figure 5.2-5). Concentrations greater than 1,000 pg/g in subsurface sediment are prevalent throughout the site, most frequently in the eastern nearshore zone from RM 2 through 8 and RM 11–11.8. Mean concentrations (see Table 5.2-4) in the eastern nearshore zone are 446 pg/g at RM 1.9–3; 638 pg/g at RM 3–4; 1,340 pg/g at RM 4–5; 561 pg/g at RM 5–6; 1,650 pg/g at RM 6–7; 19,500 pg/g at RM 7–8; 981 pg/g in Swan Island Lagoon; and 1,510 pg/g at RM 11–11.8.

Total PCDD/Fs concentrations exceed 10,000 pg/g between RM 6 and 9 in the western nearshore zone (Figure 5.2-5). Reported concentrations greater than 1,000 pg/g are located from RM 4 through 11. The highest reported concentration of 425,000 J pg/g was found in core sample WB-36 between RM 7 and 8 (Table 5.2-8). Mean concentrations in subsurface sediment in the western nearshore zone are 624 pg/g at RM 4–5; 315 pg/g at RM 5–6; 2,650 pg/g at RM 6–7; 27,300 at RM 7–8; 19,400 pg/g at RM 8–9; and 12,200 pg/g at RM 9–10.

Limited subsurface sediment data are available for the navigation channel, and most reported concentrations were less than 100 pg/g. The highest concentrations in the subsurface samples are generally found in the same areas where concentrations greater than 1,000 pg/g were reported in surface samples (Figures 5.2-5 and 5.2-6; Maps 5.2-8a–o). Reported concentration greater than 1,000 pg/g were found from RM 6 to 7 and RM 9.5 to 10.5.

Total PCDD/Fs concentrations greater than 10,000 pg/g were reported in 26 samples, 71 were between 1,000 and 10,000 pg/g (Tables 5.2-9 and 5.2-10), and overall 30 percent of the reported concentrations were greater than 1,000 pg/g. Reported concentrations between 100 and 1,000 pg/g comprise 32 percent (103 samples) of the detections, 23 percent (74 samples) were between 10 and 100 pg/g, 10 percent (31 samples) were between 1 and 10 pg/g, and 6 percent (20 samples) were less than 1 pg/g.

Downstream Reach (RM 0 to 1.9)

Total PCDD/Fs were detected in 17 of 17 samples analyzed within the Downstream Reach. Reported concentrations ranged from 0.093 to 967 pg/g; the mean concentration is 145 pg/g (Table 5.2-20). Overall, concentrations greater than 100 pg/g account for 29 percent (5 samples) of the detected results, 41 percent (7 samples) were between 10 and 100 pg/g, 12 percent (2 samples) were between 1 and 10 pg/g, and 18 percent (3 samples) were detected at concentrations less than 1 pg/g (Tables 5.2-21 and 5.2-22).

5.2.3.4 TCDD TEQ in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

TCDD TEQs were calculated for 48 of 49 surface sediment samples within the Upriver Reach. Calculated concentrations range from 0.00684 J to 2.99 pg/g (Table 5.2-11). Tables 5.2-13 and 5.2-14 show that there are three results between 1 and 10 pg/g; the majority (45 samples; 92 percent) are less than 1 pg/g. The mean TCDD TEQ concentration in this reach is 0.315 pg/g.

Downtown Reach (RM 11.8 to 15.3)

TCDD TEQs were calculated for 63 of 67 surface sediment samples within the Downtown Reach, with concentrations ranging from 0.011 J pg/g to 19.2 J pg/g with a mean of 2.61 pg/g (Table 5.2-15). TCDD TEQ concentrations in surface sediment in the Downtown Reach are shown in Map 5.2-12. Two results are between 10 and 100 pg/g, 35 detected (56 percent) are between 1 and 10 pg/g, and 26 (41 percent), are less than 1 pg/g (Tables 5.2-17 and 5.2-18).

In 2011, a remedial action was taken at the Zidell facility under DEQ authority. Table 5.2-15 presents the data statistics for the Downtown Reach excluding the Zidell data and for the Zidell data removed from the Downtown data set. None of the TCDD TEQ data was excluded from the Downtown Reach.

Study Area Reach (RM 1.9 to 11.8)

TCDD TEQs were calculated for 238 surface sediment samples. Calculated concentrations range from 0.008 J to 14,100 J pg/g, with a mean of 67.9 pg/g (Table 5.2-1). These results are plotted on Figure 5.2-7 and presented on Map 5.2-9, with concentrations greater than 10 pg/g indicated in red.

TCDD TEQ concentrations greater than 10 pg/g are present in the eastern nearshore from RM 3 through 8, in Swan Island Lagoon, and RM 11–11.8. Mean concentrations (see Table 5.2-3) in these areas are 2.95 pg/g at RM 3–4; 4.84 pg at RM 4–5; 4.40 pg/g at RM 5–6; 16.1 pg/g at RM 6–7; 11.9 pg/g at RM 7–8; 4.90 pg/g in Swan Island Lagoon; and 4.44 pg/g at RM 11–11.8.

TCDD TEQ concentrations greater than 10 pg/g in the western nearshore zone are present from RM 6 to 10. Mean concentrations (see Table 5.2-7) in these areas are 20.0 pg/g at RM 6–7; 78.5 pg/g at RM 7–8; 3.55 pg/g at RM 8–9; and 4.59 pg/g at RM 9–10. The highest calculated TCDD TEQ concentration in the surface sediment data set, 14,100 pg/g, is between RM 7 and 8.

There were no calculated concentrations in the navigation channel zone greater than 10 pg/g.

Only one sample has calculated TCDD TEQ greater than 10,000 pg/g, there are no results between 1,000 and 10,000 pg/g, 4 results (2 percent) are between 100 and 1,000 pg/g, 28 results (12 percent) are between 10 and 100 pg/g, 107 samples

(45 percent) are between 1 and 10 pg/g, and 98 results (41 percent) are less than 1 pg/g (Tables 5.2-9 and 5.2-10).

The spatial distribution of TCDD TEQ values in the Study Area is presented on Figure 5.2-7. Concentrations were higher in the western nearshore zone than in the eastern nearshore or navigation channel. The highest reported results are present in the western nearshore between RM 6.8 and 7.3, where the sample density is greater in comparison to the rest of the Study Area.

Limited data for TCDD TEQ are available for sediments in the navigation channel (Map 5.2-9). TCDD TEQ surface values within the channel were all less than 10 pg/g.

Downstream Reach (RM 0 to 1.9)

TCDD TEQs were analyzed and detected in all 21 samples within the Downstream Reach, with concentrations ranging from 0.0051 J to 2.6 J pg/g (Table 5.2-19). Tables 5.2-21 and 5.2-22 show that there are only 2 data points with concentrations ranging between 1 and 10 pg/g. The majority of the data set (19 samples; 90 percent) were detected at concentrations less than 1 pg/g. The mean TCDD TEQ concentration in this reach is 0.4 pg/g.

5.2.3.5 TCDD TEQ in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

TCDD TEQs were calculated in three subsurface sediment samples within the Upriver Reach; concentrations range from 0.656 to 2.63 pg/g (Table 5.2-12). Two results are between 1 and 10 pg/g, and the remaining result is less than 1 pg/g, with a mean concentration of 1.55 pg/g (Tables 5.2-13 and 5.2-14).

Downtown Reach (RM 11.8 to 15.3)

TCDD TEQs were calculated for 41 of 44 subsurface sediment samples within the Downtown Reach. Calculated concentrations range from 0.00226 J to 12.8 pg/g (Table 5.2-15), with a mean of 2.65 pg/g. There is a single result between 10 and 100 pg/g, 24 samples (59 percent) are between 1 and 10 pg/g, and 16 samples (39 percent) are less than 1 pg/g (Tables 5.2-17 and 5.2-18).

In 2011, a remedial action was taken at the Zidell facility under DEQ authority. Table 5.2-16 presents the data statistics for the Downtown Reach excluding the Zidell data and for the Zidell data removed from the Downtown data set. None of the TCDD TEQ data was excluded from the Downtown Reach.

Study Area Reach (RM 1.9 to 11.8)

TCDD TEQs were calculated for 313 of 331 subsurface sediment samples within the Study Area. Calculated concentrations range from 0.000262 J to 24,400 J pg/g, with a mean of 434 pg/g (Table 5.2-2). The distribution of TCDD TEQ concentrations in subsurface sediment in the Study Area is shown on Figure 5.2-8, and concentrations greater than 10 pg/g are indicated in red on Maps 5.2-8a-o and 5.2-10a-m.

Concentrations greater than 10 pg/g are present in the eastern nearshore zone from RM 1.9to 3, RM 6 to 8, and from RM 11 to 11.8. Mean concentrations (see Table 5.2-4) in these areas are 1.45 pg/g at RM 1.9–3; 5.80 pg/g at RM 6–7; 37.6 pg/g at RM 7–8; and 7.67 pg/g at RM 11–11.8.

Concentrations greater than 10 pg/g are present in the western nearshore zone from RM 4 through 9, with a prominent peak from RM 6.5 to 7.5. Mean concentrations (see Table 5.2-8) in these areas are 5.27 pg/g at RM 4–5; 2.46 pg/g at RM 5–6; 20.4 pg/g at RM 6–7; 1,570 pg/g at RM 7–8; and 36.7 pg/g at RM 8–9. The highest calculated TCDD TEQ concentration of 24,400 pg/g in subsurface sediment is at Station SD092 (0–90 cm vertically composited sample) at RM 7.2W (Map 5.2-10g).

Limited subsurface TCDD TEQ data are available from the navigation channel, and the majority of calculated results are less than 10 pg/g. The highest concentrations in subsurface sediment are generally found at the same locations where TCDD TEQ are concentrations greater than 10 pg/g in surface sediment along the eastern and western nearshore zones (Maps 5.2-8a–o and 5.2-10a-m).

Tables 5.2-9 and 5.2-10 show that there are 3 data points greater than 10,000 pg/g. There are 14 detected values between 1,000 and 10,000 pg/g and 12 samples detected at concentrations between 100 and 1,000 pg/g. An additional 42 samples are detected at concentrations ranging between 10 and 100. Another 99 samples, or 32 percent, are detected at concentrations between 1 and 10 pg/g. Approximately half the detected data set (143 samples; 46 percent) is composed of sample concentrations less than 1 pg/g.

The data show that TCDD TEQ values vary spatially along the length of the Study Area (Figure 5.2-8). In general, values were higher in the western nearshore zone than in the eastern nearshore and navigation channel zones. The most significant peak in the data in the western nearshore occurred between approximately RM 6.8 and 7.3, where data points are relatively dense in comparison to the rest of the Study Area.

Limited data for TCDD TEQ are available for sediments in the navigation channel (Map 5.2-9). TCDD TEQ surface values within the channel were relatively low, with the exception of one sample with relatively elevated concentrations near the western channel boundary at RM 6.6 (33.3 J pg/g in the interval from 132 to 243 cm bml at Station C314; Figure 5.2-8).

Downstream Reach (RM 0 to 1.9)

TCDD TEQs were analyzed in 17 samples within the Downstream Reach and detected in 16 samples (detection frequency of 94 percent), with concentrations ranging from 0.00252 to 1.53 J pg/g (Table 5.2-20). Tables 5.2-21 and 5.2-22 show that there is only one data point with concentrations ranging between 1 and 10 pg/g. The majority of the data set (15 samples; 94 percent) were detected at concentrations less than 1 pg/g. The mean TCDD TEQ concentration in this reach is 0.260 pg/g.

5.2.3.6 Total PCDD/Fs and TCDD TEQ Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas within the Study Area Reach. There are insufficient data to compare surface and subsurface concentrations in the Upriver Reach.

The surface total PCDD/Fs sediment concentrations in the Downtown Reach are slightly higher than the subsurface concentrations, while the TCDD TEQ concentrations are approximately the same. The mean surface total PCDD/Fs concentration is 1,130 pg/g and the subsurface concentration is 1,090 pg/g. The mean surface TCDD TEQ concentration is 2.61 pg/g and the subsurface sediment concentration is 2.66 pg/g.

Total PCDD/Fs and TCDD TEQ concentrations are generally greater in the subsurface sediments than in surface sediments within the Study Area as a whole. The mean total PCDD/Fs surface sediment concentration is 2,410 pg/g and the subsurface concentration is 9,050 pg/g; the mean TCDD TEQ surface sediment concentration is 68 pg/g and the subsurface concentration is 434 pg/g. Most areas throughout the Study Area Reach lack a strong or consistent vertical concentration gradient. This pattern may be due to the lack of samples and is supported by Maps 5.2-10a-m. Some exceptions to this include the area under and just upstream of the Railroad Bridge at RM 6.9, where surface layers show higher concentrations than at depth (Map 5.2-10g), and the northwest corner of Willbridge Terminal where higher levels are evident at depth (Map 5.2-10h). This suggests a recent source or sources at the former location and a historical source or sources at the latter. Elsewhere in the Study Area, significant changes in the level of PCDD/F inputs over time are generally not indicated by the data collected.

The surface total PCDD/Fs sediment concentrations in the Downstream Reach are slightly higher than the subsurface concentrations, while the TCDD TEQ concentrations are approximately the same. The mean surface total PCDD/Fs concentration is 232 pg/g, and the subsurface concentration is 67 pg/g. The mean surface TCDD TEQ concentration is 0.401 pg/g, while the subsurface sediment concentration is 260 pg/g.

5.2.4 Total DDx in Sediment

Total DDx represents the sum of the 2,4’- and 4,4’- isomers of DDD, DDE, and DDT. The distribution of total DDx concentrations at each surface sediment sampling station throughout the Study Area is depicted on Map 5.2-13; concentrations with depth at subsurface stations are depicted in detail on Maps 5.2-14a-hh. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented.

Figures 5.2-10 and 5.2-11 present scatter plots of the total DDx data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-1).

The summary statistics for total DDx in the surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigational channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present the total DDx data as orders of magnitude (e.g., <1, 1–10, 10–100, 100–1,000, etc.) for only detected values and for combined detected and non-detected values. Finally, a histogram of average surface and subsurface sediment values by river mile and for the entire Study Area is presented in Figure 5.2-12.

Data for the Upriver Reach, Downtown Reach, and Downstream Reach are only presented in statistical tables and order of magnitude tables. Additionally, surface sediment sample locations within the Downtown Reach are presented in Map 5.2-15. Summary statistics for surface and subsurface sediment within the Upriver Reach are shown in Tables 5.2-11 and 5.2-12; the number of data points by order of magnitude is provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and non-detect). Summary statistics for surface and subsurface sediment within the Downtown Reach are shown in Tables 5.2-15 and 5.2-16; the number of data points by order of magnitude is provided in Tables 5.2-17 (detect only) and 5.2-18 (detect and non-detect). Summary statistics for surface and subsurface sediment within the Downstream Reach are shown in Tables 5.2-19 and 5.2-20; the number of data points by order of magnitude is provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and non-detect).

The individual total DDT, DDD, and DDE concentrations (totals of the 2,4'- and 4,4'-isomers) are depicted in similar maps, tables, and figures as total DDx in Appendix D1.

5.2.4.1 Total DDx in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Total DDx was reported in 56 of 81 surface sediment samples within the Upriver Reach (frequency of detection 69 percent). Concentrations reported range from 0.087 J to 14.6 J µg/kg (Table 5.2-11). Tables 5.2-13 and 5.2-14 show that 1 result was reported at a concentration greater than 10 µg/kg, 41 samples were between 1 and 10 µg/kg, 14 samples (25 percent) were reported at a concentration less than 1 µg/kg. The mean concentration in this reach is 2.01 µg/kg.

Downtown Reach (RM 11.8 to 15.3)

Total DDx was reported in 130 of 149 surface sediment samples within the Downtown Reach (frequency of detection 87 percent). Reported concentrations range from 0.047 J to 73.3 J µg/kg (Table 5.2-15), with a mean concentration of 6.6 µg/kg. The spatial distribution of DDx in surface sediment is presented on Map 5.2-15.

Total DDx concentrations between 10 and 100 µg/kg were reported in 25 samples, 76 results (58 percent) were between 1 and 10 µg/kg, and 29 samples were reported at concentrations less than 1 µg/kg (Tables 5.2-17 and 5.2-18).

In 2011, a remedial action was taken at the Zidell facility under DEQ authority. Table 5.2-15 presents the data statistics for the Downtown Reach excluding the Zidell data and for the Zidell data removed from the Downtown data set. None of the total DDx data was excluded from the Downtown Reach.

Study Area Reach (RM 1.9 to 11.8)

Total DDx was reported in 1,130 of 1,249 surface sediment samples within the Study Area (frequency of detection 90 percent). Concentrations reported range from 0.051 NJ to 84,900 µg/kg (Table 5.2-1). The spatial distribution of total DDx concentrations in surface sediment is presented on Figure 5.2-10 and Map 5.2-13; concentrations greater than 100 µg/kg are observed at several locations along the nearshore zones and channel margins.

Total DDx concentrations greater than 100 µg/kg are present in the eastern nearshore zone at RM 5–7, Swan Island Lagoon, and RM 11–11.8 (Map 5.2-13). Mean concentrations in these areas are 16.6 µg/kg at RM 5–6; 18.2 µg/kg at RM 6–7; 15.7 µg/kg in Swan Island Lagoon; and 42.0 µg/kg at RM 11–11.8 (Table 5.2-3).

Total DDx concentrations greater than 100 µg/kg are present in the western nearshore zone from RM 3 through 9. The most prominent areas are between RM 6.3 and 7.5, where concentrations greater than 10,000 µg/kg were found at Station OSS002 near RM 7.2 (Table 5.2-7; Map 5.2-13). Total DDx was reported at a concentration greater than 1,000 µg/kg in a single sample at RM 8.8. Mean total DDx concentrations in these areas are 26.6 µg/kg at RM 3–4; 23.4 µg/kg at RM 4–5; 36.3 µg/kg at RM 5–6; 190 µg/kg at RM 6–7; 2,720 µg/kg at RM 7–8; and 123 µg/kg at RM 8–9 (Table 5.2-7).

Within the navigation channel, total DDx concentrations greater than 100 µg/kg were reported in four samples from three areas: RM 5.6 (maximum of 148 µg/kg), RM 6.5 (maximum of 274 J µg/kg), and RM 11.3 (maximum of 140 µg/kg). These areas are collocated with contamination present in the adjacent nearshore zones. Mean concentrations in these areas are 12.6 µg/kg at RM 5–6; 29.1 µg/kg at RM 6–7; and 25.2 µg/kg at RM 11–11.8 (Table 5.2-5).

Total DDx concentrations greater than 10,000 µg/kg were reported in 7 samples, 22 reported values were between 1,000 and 10,000 µg/kg (also located between RM 7.2W and 7.5W, with one result being at RM 8.8), 92 results were between 100 and 1,000 µg/kg, 327 results were between 10 and 100 µg/kg, 636 results were between 1 and 10 µg/kg, and 46 results (4 percent) were reported at a concentration less than 1 µg/kg (Tables 5.2-9 and 5.2-10). In all, total DDx concentrations greater than 100 µg/kg account for 11 percent of the reported results in surface sediment (Map 5.2-13).

Downstream Reach (RM 0 to 1.9)

Total DDx was reported in 22 of 25 surface sediment samples within the Downstream Reach (frequency of detection 88 percent). Concentrations reported range from 0.2 to 30 J µg/kg (Table 5.2-19). Total DDx was reported at concentrations greater than 10 µg/kg in 3 samples, 14 results (64 percent) were reported at concentrations between 1 and 10 µg/kg, and 5 results were reported at concentrations less than 1 µg/kg. The mean total DDx concentration in this reach is 5.2 µg/kg (Tables 5.2-19, 5.2-21, and 5.2-22).

5.2.4.2 Total DDx in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

Only three subsurface sediment samples were analyzed for total DDx, all between RM 15.4 and 16. Total DDx was reported in all three samples at concentrations from 0.99 to 9.74 µg/kg, with a mean of 5.83 µg/kg.

Downtown Reach (RM 11.8 to 15.3)

Total DDx was reported in 64 of 94 subsurface sediment samples within the Downtown Reach (frequency of detection 68 percent). Concentrations reported range from 0.052 to 301 µg/kg (Table 5.2-16), with a mean concentration of 16.3 µg/kg. One result was reported at a concentration greater than 100 µg/kg, 19 results were reported at concentrations between 10 and 100 µg/kg, 32 results were between 1 and 10 µg/kg, and 11 results were reported at concentrations less than 1 µg/kg (Tables 5.2-17 and 5.2-18). No subsurface samples were collected in the vicinity of the Zidell facility.

Study Area Reach (RM 1.9 to 11.8)

Total DDx was reported in 1,393 of 1,678 subsurface samples in the Study Area Reach (frequency of detection 83 percent). Concentrations reported range from 0.0580 J to 3,640,000 µg/kg (Table 5.2-2), with a mean concentration of 11,200 µg/kg. The spatial distribution of total DDx in the subsurface sediment is presented on Figure 5.2-11 and Maps 5.2-14a-hh.

Areas in the eastern nearshore zone where total DDx is reported at concentrations greater than 100 µg/kg total include RM 2–3 (a single result), RM 3.5–7.5, Swan Island Lagoon, and RM 11–11.8. The extent of total DDx greater than 100 µg/kg is confined to a relatively small area at RM 11, and more widely dispersed in Swan Island Lagoon (Maps 5.2-14a-hh). Mean concentrations in these areas are 14.4 µg/kg at RM 1.9–3; 87.1 µg/kg at RM 3–4; 21.7 µg/kg at RM 4–5; 56.2 µg/kg at RM 5–6; 103 µg/kg at RM 6–7; 41.4 µg/kg at RM 7–8; 65.1 µg/kg in Swan Island Lagoon; and 45.5 µg/kg at RM 11–11.8 (Figure 5.2-11, Table 5.2-4).

Areas in the western nearshore zone where total DDx concentrations are greater than 100 µg/kg extend from RM 3 through 10, with concentrations greater than 10,000 µg/kg present between RM 7 and 7.5 (Map 5.2-13). The maximum reported subsurface concentration was found in the interval 323 to 384 cm bml at Station WB-24 at RM 7.2.

Total DDx at concentrations greater than 1,000 µg/kg were reported from approximately RM 6. 1 to 8.8. Mean concentrations in these areas are 39.4 µg/kg at RM 3–4; 77.0 µg/kg at RM 4–5; 78.4 µg/kg at RM 5– 6; 322 µg/kg at RM 6–7; 36,900 µg/kg at RM 7–8; and 153 µg/kg at RM 8–9 (Table 5.2-8).

Areas where total DDx concentrations are greater than or equal to 100 µg/kg within the navigation channel are located from RM 4.1 to 5, RM 6.4 to 7.1, and RM 9.5 to 11.5 (Figure 5.2-12), and generally correspond with contamination found in the adjacent nearshore zones. Mean concentrations in these areas are 73.9 µg/kg at RM 4–5; 19.2 µg/kg at RM 5–6; 229 µg/kg at RM 6–7; 67.1 µg/kg at RM 7–8; 8.87 µg/kg at RM 9–10; 14.6 µg/kg at RM 10–11; and 10.8 µg/kg at RM 11–11.8.

Total DDx concentrations greater than 10,000 µg/kg were reported in 51 results, 83 results were between 1,000 and 10,000 µg/kg, 200 results (14 percent of the detected data) were between 100 and 1,000 µg/kg, 489 results (35 percent of the detected data) were between 10 and 100 µg/kg, 425 results (31 percent) were between 1 and 10 µg/kg, and 145 results (10 percent) were reported at a concentration less than 1 µg/kg (Tables 5.2-9 and 5.2-10). Total DDx concentrations greater than 100 µg/kg account for 24 percent of the detected results.

Downstream Reach (RM 0 to 1.9)

Total DDx was reported in 17 of 26 subsurface sediment samples within the Downstream Reach (frequency of detection 65 percent). Concentrations reported range from 0.28NJ to 80 NJ µg/kg (Table 5.2-20). Total DDx concentrations between 10 and 100 µg/kg were reported in 11 results, 4 results were between 1 and 10 µg/kg, and 2 results were reported at a concentration less than 1 µg/kg. The mean concentration in this reach is 19 µg/kg (Tables 5.2-21 and 5.2-22).

5.2.4.3 Total DDx Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas within the Study Area Reach. There are insufficient data to compare surface and subsurface concentrations in the Upriver Reach. The mean concentration in surface sediment in this reach is 2.01 µg/kg.

Total DDx concentrations in the Downtown Reach are lower in surface sediment than in subsurface sediment. Mean concentrations are 6.59 and 16.3 µg/kg in surface and subsurface sediment, respectively.

Within the Study Area, mean total DDx concentrations in subsurface sediment are generally higher than in surface sediment (Figure 5.2-12).

Areas where total DDx concentrations are greater than 100 µg/kg in subsurface sediment generally align with the locations where surface sediment concentrations are greater than 100 µg/kg (Maps 5.2-13 and 5.2-14a-hh; Figures 5.2-10, 5.2-11, and 5.2-12). Exceptions occur in the eastern nearshore zone from RM 3 to 5 and RM 7 to 8, the navigation channel from RM 7 to 11, and the western nearshore area from RM 9 to 10 where subsurface concentrations exceed 100 µg/kg, but surface sediment concentrations do not.

Within the Downstream Reach, total DDx concentrations in subsurface sediment concentrations are greater than surface sediment concentrations. Mean concentrations are 5.2 and 19 µg/kg in surface and subsurface sediment, respectively.

5.2.5 Total PAHs in Sediment

Total PAHs is defined as the sum of the individual PAH compound concentrations. The distribution of total PAHs concentrations at each surface sediment sampling station throughout the Study Area is depicted on Map 5.2-16; concentrations with depth at subsurface stations are depicted in detail on Maps 5.2-17a-hh. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented.

Figures 5.2-13 and 5.2-14 present scatter plots of the total PAHs data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-1).

The summary statistics for total PAHs in the surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigational channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present the total PAHs data as orders of magnitude (e.g., <1, 1–10, 10–100, 100–1,000, etc.) for only detected values and for combined detected and non-detected values. Finally, a histogram of average surface and subsurface sediment values by river mile and for the entire Study Area is presented in Figure 5.2-15.

Data sets for the Upriver Reach, Downtown Reach, and Downstream Reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown Reach surface sediment samples are presented in Map 5.2-18. Summary statistics for surface and subsurface sediment within the Upriver Reach are shown in Tables 5.2-11 and 5.2-12; the number of data points by order of magnitude is provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and non-detect). Summary statistics for surface and subsurface sediment within the Downtown Reach are shown in Tables 5.2-15 and 5.2-16; the number of data points by order of magnitude is provided in Tables 5.2-17 (detect only) and 5.2-18 (detect and non-detect). Summary statistics for surface and subsurface sediment within the Downstream Reach are shown in Tables 5.2-19 and 5.2-20; the number of data points by order of magnitude is provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and non-detect).

5.2.5.1 Total PAHs Data Set

Frequencies of detection of PAH compounds were high, approximately 99 percent in surface samples and 95 percent in subsurface samples. The Study Area data set of total PAHs concentrations includes 1,661 surface samples and 1,715 subsurface samples. The Upriver data set includes 78 surface samples and 3 subsurface samples. The downtown data set includes 269 surface samples and 161 subsurface samples. The downstream data set includes 25 surface samples and 26 subsurface samples.

5.2.5.2 Total PAHs in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Total PAHs were reported in 63 of 78 surface sediment samples within the Upriver Reach (frequency of detection 81 percent). Concentrations reported range from 0.91 J to 1,510 µg/kg (Table 5.2-11). Tables 5.2-13 and 5.2-14 show that only 1 result was reported at a concentration greater than 1,000 µg/kg, 17 (27 percent of the detected data set) were between 100 and 1,000 µg/kg, 39 results (62 percent) were between 10 and 100 µg/kg, 5 were between 1 and 10 µg/kg, and 1 result was reported at a concentration less than 1 µg/kg. The mean total PAHs concentration in this reach is 107 µg/kg.

Downtown Reach (RM 11.8 to 15.3)

Total PAHs were reported in 248 of 269 surface sediment samples within the Downtown Reach (frequency of detection 92 percent). Concentrations reported range from 0.0734 to 62,500 µg/kg (Table 5.2-15), with a mean of 2,174 µg/kg. The spatial distribution of total PAHs in the Downtown Reach is presented on Map 5.2-18. Reported concentrations greater than 10,000 µg/kg were observed at RM 12.2W, 12.5W, between 13.5W and 14W, and at 12.3E.

Total PAHs were reported at a concentration greater than 10,000 µg/kg in 11 results, 55 were between 1,000 and 10,000 µg/kg, 121 (49 percent) were between 100 and 1,000 µg/kg, 41 (17 percent) were between 10 and 100 µg/kg, 17 were between 1 and 10 µg/kg, and 3 results were reported at a concentration less than 1 µg/kg (Tables 5.2-17 and 5.2-18). Within this reach, 27 percent of the detected results were reported at a concentration greater than 1,000 µg/kg.

In 2011, a remedial action was taken at the Zidell facility under DEQ authority. Table 5.2-15 presents the data statistics for the Downtown Reach excluding the Zidell data and for the Zidell data removed from the Downtown data set. The Zidell data set includes total PAHs from 112 surface sediment samples (frequency of detection 88 percent). Concentrations reported range from 0.0734 to 32,000 µg/kg, with a mean of 2,538 µg/kg. When the data for the Zidell facility are removed from the downtown data set (Table 5.2-15), reported total PAHs concentrations in surface sediment range from 0.57J to 62,500 µg/kg, with a mean of 1,940 µg/kg.

Study Area Reach (RM 1.9 to 11.8)

Total PAHs were reported in 1,640 of 1,661 surface sediment samples within the Study Area (frequency of detection 99 percent). Concentrations reported range from 3.30 J to 7,260,000 µg/kg (Table 5.2-1). The distribution of reported concentrations varies throughout the Study Area, and is particularly heterogeneous above RM 6.5 where sample density is greater (Figure 5.2-13).

Areas where total PAHs concentrations are generally less than 10,000 µg/kg are found in several locations within the Study Area, including the lower end of the Study Area from RM 1.9W to 3W, the upper end of the Study Area from RM 10 to 11.8 (except three samples in the eastern nearshore zone), and in the eastern nearshore zone between RM 6 and 10. The only area in the navigation channel with reported concentrations greater than 10,000 µg/kg is from RM 5 to 7 (Figure 5.2-13; Map 5.2-16).

Reported concentrations greater than 1,000 µg/kg are located throughout the Study Area; areas with concentrations greater than 20,000 µg/kg were encountered in the eastern nearshore zone from RM 4.2 to 4.8 and in the western nearshore zone from RM 5.9 to 6.8 (Figure 5.2-13; Map 5.2-16). The highest reported total PAHs concentration in surface sediment of 7,260,000 µg/kg was reported in the navigation channel at RM 5.7 (Station G225). Total PAHs concentrations greater than 20,000 µg/kg were also found adjacent to the western nearshore zone in surface sediment in the navigation channel from RM 5.2 to 6.8.

Mean total PAHs concentrations by river mile for areas in the eastern nearshore zone with reported concentrations greater than 1,000 µg/kg are 5,160 µg/kg at RM 1.9–3; 3,850 µg/kg at RM 3–4; 35,100 µg/kg at RM 4–5; 5,170 µg/kg at RM 5–6; 3,870 µg/kg at RM 6–7; 1,420 µg/kg at RM 7–8; 3,580 µg/kg in Swan Island Lagoon; 4,850 µg/kg at RM 10–11; and 3,640 µg/kg at RM 11–11.8 (Table 5.2-3).

Mean concentrations by river mile for areas in the western nearshore zone with reported concentrations greater than 1,000 µg/kg are 4,740 µg/kg at RM 3–4; 7,940 µg/kg at RM 4–5; 17,300 µg/kg at RM 5–6; 192,000 µg/kg at RM 6–7; 3,490 µg/kg at RM 7–8; 2,280 µg/kg at RM 8–9; and 2,510 µg/kg at RM 9–10 (Table 5.2-7).

Mean total PAHs concentrations by river mile in the navigation channel for areas where concentrations are greater than 1,000 µg/kg are 275,000 µg/kg at RM 5–6 and 58,600 µg/kg at RM 6–7 (Table 5.2-5).

Total PAHs concentrations greater than 10,000 µg/kg were reported in 233 results, 636 were between 1,000 and 10,000 µg/kg, 661 were between 100 and 1,000 µg/kg, 104 were between 10 and 100 µg/kg, and 6 results were reported at concentrations ranging from 1 to 10 µg/kg (Tables 5.2-9 and 5.2-10). Fifty-five percent of the results within the Study Area were reported at concentrations greater than 1,000 µg/kg (Map 5.2-16).

Downstream Reach (RM 0 to 1.9)

Total PAHs were reported in 25 of 25 surface sediment samples within the Downstream Reach. Concentrations reported range from 1.4J to 18,000J µg/kg (Table 5.2-19). One result was reported at a concentration greater than 10,000 µg/kg, 1 was between 1,000 and 10,000 µg/kg, 16 were between 100 and 1,000 µg/kg, 6 were between 10 and 100 µg/kg, and 1 result was between 1 and 10 µg/kg (Tables 5.2-21 and 5.2-22). The mean total PAHs concentration in this reach is 1,120 µg/kg.

5.2.5.3 Total PAHs in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

Total PAHs were reported in three of three samples collected between RM 15.4 and 16. Concentrations reported range from 253 µg/kg to 533 µg/kg, with a mean of 366 µg/kg.

Downtown Reach (RM 11.8 to 15.3)

Total PAHs were reported in 157 of 161 subsurface sediment samples within the Downtown Reach (frequency of detection 98 percent). Concentrations reported range from 0.25J to 4,850,000 µg/kg (Table 5.2-16), with a mean of 219,700 µg/kg. Total PAHs concentrations greater than 10,000 µg/kg were reported in 30 results, 39 results were between 1,000 and 10,000 µg/kg, 52 results were between 100 and 1,000 µg/kg, 23 results were between 10 and 100 µg/kg, 6 were between 1 and 10 µg/kg, and 7 results were reported at concentrations less than 1 µg/kg (Tables 5.2-17 and 5.2-18). Within this reach, reported concentrations greater than 1,000 µg/kg account for 44 percent of the detected results, with the highest concentrations observed in the western nearshore area at RM 12.2 (Figure 5.2-14).

Twelve of the subsurface samples were collected in the vicinity of the Zidell facility, and reported concentrations ranged from 4.8 to 451 µg/kg. With these values excluded, the mean and median total PAHs concentrations are 235,000 and 770 µg/kg, respectively.

Study Area Reach (RM 1.9 to 11.8)

Total PAHs were reported in 1,643 of 1,715 subsurface samples (frequency of detection 96 percent). Concentrations reported range from 0.150 J to 53,300,000 µg/kg (Table 5.2-2).

Areas where total PAHs concentrations exceeded 10,000 µg/kg were observed in the eastern nearshore zone between RM 3.5 and 7.5, in Swan Island Lagoon, and at RM 11.2. Mean concentrations by river mile in these areas are 22,000 µg/kg at RM 3–4; 23,500 µg/kg at RM 4–5; 11,600 µg/kg at RM 5–6; 6,560 µg/kg for RM 6–7; 3,010 µg/kg at RM 7–8; 3,400 µg/kg in Swan Island Lagoon; and 2,790 µg/kg for RM 11–11.8 (Table 5.2-4).

Locations in the western nearshore where total PAHs concentrations greater than 10,000 µg/kg are observed include RM 3 to 7.5 and at RM 9.2 (Figure 5.2-16 and Maps 5.2-17a-hh). The highest concentrations in subsurface sediment are found between RM 6 and 6.5, and the highest reported value of 53,300,000 µg/kg was observed in this area at Station C302. Mean concentrations by river mile in these areas are 19,000 µg/kg at RM 3–4; 24,700 µg/kg at RM 4–5; 45,400 µg/kg at RM 5–6; 1,610,000 µg/kg at RM 6–7; 3,560 µg/kg at RM 7–8; and 19,200 µg/kg at RM 9–10 (Table 5.2-8).

Total PAHs concentrations greater than 10,000 µg/kg were also observed in subsurface sediment in the navigation channel from RM 4 to 6.5, adjacent to and downstream from the high concentration area in the western nearshore zone between RM 6 and 6.5, and at RM 7.9. Mean concentration by river mile in this area are 5,240 µg/kg at RM 4–5; 8,450 µg/kg at RM 5–6; 453,000 µg/kg at RM 6–7; and 1,350 µg/kg at RM 7–8 (Table 5.2-6).

Within the Study Area, total PAHs concentrations greater than 10,000 µg/kg were reported in 335 results, 563 were between 1,000 and 10,000 µg/kg, 484 were reported at concentrations between 100 and 1,000 µg/kg, 137 were detected at concentrations between 10 and 100 µg/kg, 87 were between 1 and 10 µg/kg, and 37 results were reported at concentrations less than 1 µg/kg. Concentrations greater than 1,000 µg/kg account for 54 percent of the reported results within the Study Area (Tables 5.2-9 and 5.2-10)

Downstream Reach (RM 0 to 1.9)

Total PAHs were reported in all 26 subsurface sediment samples collected within the Downstream Reach. Concentrations reported range from 0.49J to 23,000 µg/kg (Table 5.2-20). Tables 5.2-21 and 5.2-22 show that one result was reported at a concentration greater than 10,000 µg/kg, 4 were between 1,000 and 10,000 µg/kg, 10 were between 100 and 1,000 µg/kg, 7 results were reported at concentrations between 10 and 100 µg/kg, 2 were between 1 and 10 µg/kg, and 2 results were reported at a concentration less than 1 µg/kg. Within the Downstream Reach, reported concentrations greater than 1,000 µg/kg account for 19 percent of the reported results in subsurface sediment. The mean total PAHs concentration in the Downstream Reach is 1,339 µg/kg.

5.2.5.4 Total PAHs Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas within the Study Area Reach.

There are insufficient data to compare surface and subsurface concentrations in the Upriver Reach. The mean surface sediment total PAHs concentration in this reach is 107 µg/kg.

Total PAHs concentrations within the Downtown Reach are greater in subsurface sediment relative to concentrations observed in surface sediment. Mean concentrations are 2,174 and 219,700 µg/kg in surface and subsurface sediment, respectively.

Within the Study Area, total PAHs concentrations are generally greater in subsurface than in surface sediments. Mean concentrations in surface and subsurface sediments are 27,200 and 246,000 µg/kg, respectively (Tables 5.2-1 and 5.2-2). Localized areas where concentrations are greater in surface sediment are found from RM 1.9 to 3, 4 to 5, Swan Island Lagoon, and RM 10 to 11.8 within the eastern nearshore zone; RM 8 to 9 in the western nearshore zone; and RM 5 to 6, 8 to 9, and 9 to 10 within the navigation channel.

Areas with the highest reported total PAHs concentrations in both surface and subsurface sediment generally align (Maps 5.2-17a-hh and Figures 5.2-13, 5.2-14, and 5.2-15).

Within the Downstream Reach, total PAHs concentrations are greater in subsurface than in surface sediment. Mean concentrations are 1,120 and 1,339 µg/kg in surface and subsurface sediment, respectively.

5.2.6 Bis(2-ethylhexyl)phthalate in Sediment

The distribution of BEHP concentrations at each surface sediment sampling station throughout the Study Area is depicted on Map 5.2-19; concentrations with depth at subsurface stations are depicted on Maps 5.2-20a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented.

Figures 5.2-16 and 5.2-17 present scatter plots of the BEHP data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-1).

The summary statistics for BEHP in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present BEHP data as orders of magnitude (e.g., <1, 1–10, 10–100, 100–1,000, etc.) for only detected values and for combined detected and non-detected values. Finally, a histogram of average surface and subsurface sediment values by river mile and for the entire Study Area is presented in Figure 5.2-18.

Data sets for the Upriver Reach, Downtown Reach, and Downstream Reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown Reach surface sediment samples are presented in Map 5.2-21. Summary statistics for surface and subsurface sediment within the Upriver Reach are shown in Tables 5.2-11 and 5.2-12; the number of data points by order of magnitude is provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and non-detect). Summary statistics for surface and subsurface sediment within the Downtown Reach are shown in Tables 5.2-

15 and 5.2-16; the number of data points by order of magnitude is provided in Tables 5.2-17 (detect only) and 5.2-18 (detect and non-detect). Summary statistics for surface and subsurface sediment within the Downstream Reach are shown in Tables 5.2-19 and 5.2-20; the number of data points by order of magnitude is provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and non-detect).

5.2.6.1 BEHP Data Set

The Study Area data set of BEHP concentrations includes 1,513 surface and 1,591 subsurface samples, the Upriver data set includes 72 surface and 3 subsurface samples, the downtown data set includes 96 surface samples and 64 subsurface samples, and the downstream data set includes 21 surface and 17 subsurface samples. Because the reporting limit for several non-detect results was greater than the maximum reported values (Figures 5.2-16 and 5.2-17), the majority of this discussion will focus on detected values.

5.2.6.2 BEHP in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

BEHP was reported in 56 of 72 surface sediment samples and within the Upriver Reach (frequency of detection 78 percent). Concentrations reported range from 4.2 J to 2,100 µg/kg (Table 5.2-11). One result was reported at a concentration greater than 1,000 µg/kg, 9 were between 100 and 1,000 µg/kg, 40 results were between 10 and 100 µg/kg, and 6 were between 1 and 10 µg/kg (Tables 5.2-13 and 5.2-14). The mean BEHP concentration in this reach is 94 µg/kg.

Downtown Reach (RM 11.8 to 15.3)

BEHP was reported in 78 of 96 surface sediment samples within the Downtown Reach (frequency of detection 81 percent). Concentrations reported range from 7.6 J to 18,000 µg/kg (Table 5.2-15), with a mean of 418 µg/kg. The spatial distribution of BEHP in surface sediment is presented on Map 5.2-21.

Within the Downtown Reach, 1 result was reported at a concentration greater than 10,000 µg/kg, 1 result was between 1,000 and 10,000 µg/kg, 32 were between 100 and 1,000, 39 were between 10 and 100 µg/kg, and 5 results were reported at concentrations between 1 and 10 µg/kg (Tables 5.2-17 and 5.2-18).

In 2011, a remedial action was taken at the Zidell facility under DEQ authority. Table 5.2-15 presents the data statistics for the Downtown Reach excluding the Zidell data and for the Zidell data removed from the Downtown data set. None of the BEHP data was excluded from the Downtown Reach.

Study Area Reach (RM 1.9 to 11.8)

BEHP was reported in 932 of 1,513 surface sediment samples within the Study Area (frequency of detection 62 percent). Concentrations reported range from 7.00 J to 440,000J µg/kg (Table 5.2-1), with a mean of 1,050 µg/kg. The spatial distribution of BEHP in surface sediment is presented on Figure 5.2-16.

Areas where BEHP concentrations are greater than 1,000 µg/kg were observed in the eastern nearshore zone between RM 3.8 and 4.1 and in the International Terminals Slip, in Swan Island Lagoon, between RM 7 and 8 and at RM 11.2 (Figure 5.2-16, Map 5.2-19). The highest reported surface concentration in the Study Area of 440,000 J µg/kg was found at Station G367 at the mouth of Swan Island Lagoon. Mean BEHP concentrations by river mile in these areas are 1,310 µg/kg at RM 3–4; 792 µg/kg at RM 4–5; 573 µg/kg at RM 7–8; 6,150 µg/kg in Swan Island Lagoon; and 204 µg/kg at RM 11–11.8 (Table 5.2-3)

BEHP concentrations greater than 1,000 µg/kg were observed in the western nearshore zone from RM 6 through 10, with a prominent peak at RM 8.8 (Figure 5.2-16). Mean concentrations by river mile are 256 µg/kg at RM 6–7; 347 µg/kg at RM 7–8; 745 µg/kg at RM 8–9; and 531 µg/kg at RM 9–10 (Table 5.2-7).

The greatest concentrations observed in the navigation channel zone are located near RM 10 (Map 5.2-19). Additional elevated concentrations are located at RM 5.2, Swan Island Lagoon, and RM 10.3 near the western nearshore area (Map 5.2-19). Mean concentrations in these areas are 203 µg/kg at RM 5–6; 679 µg/kg in Swan Island Lagoon; and 446 µg/kg at RM 10–11 (Table 5.2-5).

BEHP concentrations greater than 10,000 µg/kg were reported in 9 results, 79 were between 1,000 and 10,000 µg/kg, 501 (54 percent of the detected results) were reported at concentrations between 100 and 1,000 µg/kg, 336 were between 10 to 100 µg/kg, and 7 results were reported at concentrations between 1 and 10 µg/kg (Table 5.2-9).

Downstream Reach (RM 0 to 1.9)

BEHP was reported in 10 of 21 surface sediment samples within the Downstream Reach (frequency of detection 48 percent). Concentrations were reported from 7.1 J to 170 µg/kg (Table 5.2-19). Two results were reported at a concentration greater than 100 µg/kg, seven were between 10 and 100 µg/kg, and one result was less than 10 µg/kg. The mean BEHP concentration in this reach is 64 µg/kg (Tables 5.2-21 and 5.2-22).

5.2.6.3 BEHP in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

Three subsurface sediment samples were collected and analyzed for BEHP between RM 15.4 and 16. BEHP was reported in all three samples, and concentrations reported range from 20 J to 3,800 µg/kg, with a mean of 1,300 µg/kg.

Downtown Reach (RM 11.8 to 15.3)

BEHP was reported in 36 of 64 subsurface sediment samples within the Downtown Reach (frequency of detection 56 percent). Concentrations reported range from 2.5 J to 815 µg/kg with a mean of 103 µg/kg (Table 5.2-16). Eight results were reported at concentrations greater than 100 µg/kg, 23 results were between 1 and 10 µg/kg, and

5 results were reported at a concentration less than 10 µg/kg (Table 5.2-17). None of the subsurface samples were collected in the vicinity of the Zidell facility.

Study Area Reach (RM 1.9 to 11.8)

Within the Study Area, BEHP was reported in 635 of 1,591 subsurface samples (frequency of detection 40 percent). Concentrations reported range from 2.40 J to 18,000 µg/kg (Table 5.2-2), with a mean of 345 µg/kg. The spatial distribution of BEHP concentrations in subsurface sediment is presented on Figure 5.2-17 and Maps 5.2-20a-o.

Table 5.2-9 shows that there are two data points greater than 10,000 µg/kg. There are 32 detected values between 1,000 and 10,000 µg/kg, which are primarily located within the peak areas discussed above. Subsurface sediment samples greater than 1,000 µg/kg account for 5 percent of the detected data set. An additional 257 samples, 40 percent of the detected data set, were detected at concentrations between 100 and 1,000 µg/kg. Half of the detected data set (317 samples) is between 10 and 100 µg/kg. An additional 27 samples (4 percent) are composed of concentrations ranging between 1 and 10 µg/kg, and there were no samples detected at a concentration less than 1 µg/kg.

Areas where BEHP concentrations greater than 1,000 µg/kg are observed in subsurface sediment are present in the eastern nearshore between RM 3.6 and 4.4 and in the International Terminals Slip, and in Swan Island Lagoon (Figure 5.2-17, Maps 5.2-20a-o). Mean concentrations (Table 5.2-3) in these areas are 586 µg/kg at RM 3–4; 196 µg/kg at RM 4–5; and 650 µg/kg in Swan Island Lagoon.

Areas in the western nearshore zone where BEHP concentrations are greater than 1,000 µg/kg are observed from RM 6 through 10 (Figure 5.2-17; Maps 5.2-20g,h,j,k). Mean concentrations by river mile in this area are 338 µg/kg at RM 6–7; 277 at RM 7–8; 628 µg/kg at RM 8–9; and 359 µg/kg at RM 9–10 (Table 5.2-7).

Within the navigation channel, concentrations greater than 1,000 µg/kg of BEHP are observed at RM 7.9 (which appears most likely associated the reported concentrations in Swan Island Lagoon; Map 5.2-20i), and a single result at RM 10.3 near the western nearshore area (Map 5.2-20l). Mean BEHP concentrations in these areas are 910 µg/kg for RM 7 to 8; and 502 µg/kg for RM 10 to 11 (Table 5.2-6). The maximum reported concentration of 18,000 µg/kg in subsurface sediment was from the navigation channel, from the interval of 0–195 cm bml at Station WR-VC-110 (RM 10.3).

Downstream Reach (RM 0 to 1.9)

BEHP was reported in 16 of 17 subsurface sediment samples within the Downstream Reach (frequency of detection 94 percent). Concentrations reported range from 3.1 J to 39 µg/kg (Table 5.2-20). Five results were reported at concentrations greater than 10 µg/kg and 11 were less than 10 µg/kg. The mean concentration in this reach is 8.2 J µg/kg (Tables 5.2-21 and 5.2-22).

5.2.6.4 BEHP Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas within the Study Area Reach.

There are insufficient data to compare surface and subsurface concentrations in the Upriver Reach. The mean BEHP surface sediment concentration in this reach is 94 µg/kg.

The surface BEHP sediment concentrations in the Downtown Reach are greater than the subsurface concentrations, and are 418 and 103 µg/kg, respectively.

Within the Study Area, BEHP concentrations are generally greater in surface than in subsurface sediments; mean concentration are 1,050 and 345 µg/kg in surface and subsurface sediment, respectively (Tables 5.2-1 and 5.2-2). Exceptions to this general trend are observed in the eastern nearshore zone at RM 5–6 where mean surface and subsurface concentrations are similar, and RM 8–9 where the mean concentration in subsurface sediment is approximately twice that surface sediment (Tables 5.2-3 and 5.2-4). The maximum BEHP concentrations in surface and subsurface sediment in the eastern nearshore zone are both found in Swan Island Lagoon.

Within the western nearshore zone, localized areas where BEHP concentrations are greater in subsurface sediment include RM 5–6, where the mean subsurface concentration is an order of magnitude greater than the mean surface concentration, and RM 7–8, where mean surface and subsurface concentrations are similar. The maximum reported BEHP concentration in surface sediment in the western nearshore zone was located between RM 7 and 8, while the maximum reported concentration in subsurface sediment was located between RM 5 and 6.

Within the navigation channel, the mean BEHP concentration in subsurface sediment at RM 7 to 8 is approximately 3 times the mean surface concentration. The maximum reported surface and subsurface BEHP concentrations in the navigation channel were reported at RM 10 to 11.

Within the Downstream Reach, mean BEHP concentrations are greater in surface sediment (64 and 11 µg/kg in surface and subsurface sediment, respectively).

5.2.7 Total Chlordanes in Sediment

The distribution of total chlordanes concentrations at each surface sediment sampling station throughout the Study Area is depicted on Map 5.2-22; concentrations with depth at subsurface stations are depicted on Maps 5.2-23a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented.

Figures 5.2-19 and 5.2-20 present scatter plots of the total chlordanes data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-1).

Summary statistics for total chlordanes in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present total chlordanes data by orders of magnitude (e.g., <1, 1–10, 10–100, 100–1,000, etc.) for detected-only values and for combined detected and non-detected values. Finally, a histogram of average surface and subsurface sediment values by river mile and for the entire Study Area is presented in Figure 5.2-21.

Data sets for the Upriver Reach, Downtown Reach, and Downstream Reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown Reach surface sediment samples are presented in Map 5.2-24. Summary statistics for surface and subsurface sediment within the Upriver Reach are shown in Tables 5.2-11 and 5.2-12; the number of data points by order of magnitude is provided in Tables 5.2-13 (detects only) and 5.2-14 (detects and non-detects). Summary statistics for surface and subsurface sediment within the Downtown Reach are shown in Tables 5.2-15 and 5.2-16; the number of data points by order of magnitude is provided in Tables 5.2-17 (detects only) and 5.2-18 (detects and non-detects). Summary statistics for surface and subsurface sediment within the Downstream Reach are shown in Tables 5.2-19 and 5.2-2; the number of data points by order of magnitude is provided in Tables 5.2-21 (detects only) and 5.2-22 (detects and non-detects).

5.2.7.1 Total Chlordanes Data Set

The Study Area data set of total chlordanes concentrations includes 1,193 surface and 1,214 subsurface samples, the Upriver data set includes 77 surface and 3 subsurface samples, the downtown data set includes 145 surface and 94 subsurface samples, and the downstream data set includes 25 surface and 26 subsurface samples. Several non-detect results had reporting limits greater than the maximum reported concentrations (Figures 5.2-19 and 5.2-20); thus, the majority of this discussion will focus on the detected values only as meaningful conclusions cannot be drawn from the elevated non-detected values.

5.2.7.2 Total Chlordanes in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Total chlordanes were detected in 38 of 77 surface sediment samples within the Upriver Reach (frequency of detection 49 percent). Concentrations reported range from 0.057 J to 1.53 µg/kg (Table 5.2-11). Two results were reported at a concentration greater than 1 µg/kg, and the remaining 36 detections were all reported at concentrations less than 1 µg/kg (Table 5.2-13). The mean concentration in this reach is 0.391 µg/kg.

Downtown Reach (RM 11.8 to 15.3)

Total chlordanes were reported in 110 of 145 surface sediment samples within the Downtown Reach (frequency of detection 76 percent). Concentrations reported range from 0.039 J to 23.2 J µg/kg (Table 5.2-15), and the mean concentration is 1.29 µg/kg. The spatial distribution of total chlordanes in surface sediment within the Downtown Reach is shown on Map 5.2-24.

Within the Downtown Reach, total chlordanes were reported at a concentration greater than 10 µg/kg in 2 results, 35 were between 1 and 10 µg/kg, and 73 results were reported at concentrations less than 1 µg/kg (Table 5.2-17).

In 2011, a remedial action was taken at the Zidell facility under DEQ authority. Table 5.2-15 presents the data statistics for the Downtown Reach excluding the Zidell data and for the Zidell data removed from the Downtown data set. None of the total chlordanes data was excluded from the Downtown Reach.

Study Area Reach (RM 1.9 to 11.8)

Total chlordanes were reported in 761 of 1,193 surface sediment samples within the Study Area (frequency of detection 64 percent). Concentrations reported range from 0.0310 J to 669 NJ µg/kg (Table 5.2-1), with a mean concentration in surface sediment of 5.03 µg/kg. The spatial distribution of reported total chlordanes concentrations in surface sediment within the Study Area is presented on Figure 5.2-19.

Areas in the eastern nearshore zone with reported concentrations greater than 10 µg/kg were observed at RM 2.8, 3.8, 5.5, Swan Island Lagoon, and RM 11 (Figure 5.2-19 and Map 5.2-22). The highest surface concentration detected in the eastern nearshore zone (60 µg/kg) was found at Station GCA11E at RM 11. Mean concentrations in these areas are 1.15 µg/kg at RM 2–3; 1.48 µg/kg at RM 3–4; 2.37 µg/kg at RM 5–6; 2.75 µg/kg in Swan Island Lagoon; and 11.4 µg/kg at RM 11–11.8 (Table 5.2-3).

Areas in the western nearshore zone with reported total chlordanes concentrations greater than 10 µg/kg were observed from RM 5.8 through 9 (Figure 5.2-19). The maximum reported concentration in surface sediment of 669 NJ µg/kg was at Station G355 (RM 7.3W). Mean concentrations in the western nearshore zone are 1.75 µg/kg at RM 5–6; 12.5 µg/kg at RM 6–7; 24.9 µg/kg at RM 7–8; and 28.9 µg/kg at RM 8–9. Within the navigation channel there were no reported concentrations greater than 10 µg/kg (Table 5.2-5).

Table 5.2-9 shows that there are 761detected data points in surface sediment. Total chlordanes concentrations greater than 100 µg/kg were reported in 3 results, 46 were between 10 and 100 µg/kg, 270 detected results were between 1 and 10 µg/kg, and 442 results (58 percent of detections) were reported at concentrations less than 1 µg/kg.

Downstream Reach (RM 0 to 1.9)

Total chlordanes were reported in 15 of 25 surface sediment samples within the Downstream Reach (frequency of detection 60 percent). Concentrations reported range from 0.067 NJ to 4.5 J µg/kg (Table 5.2-19). Three results were reported at a concentration greater than 1 µg/kg, and the remaining 12 results were all less than 1 µg/kg (Table 5.2-21), with a mean of 0.812 µg/kg.

5.2.7.3 Total Chlordanes in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

Only three subsurface sediment samples were analyzed for total chlordanes in the Upriver Reach, all collected between RM 15.4 and 16. Total chlordanes were reported in all three results, from 0.187 to 2.93 µg/kg, with a mean of 1.34 µg/kg.

Downtown Reach (RM 11.8 to 15.3)

Total chlordanes were reported in 51 of 94 subsurface sediment samples within the Downtown Reach (frequency of detection 54 percent). Concentrations reported range from 0.094 J to 54 J µg/kg (Table 5.2-16), with a mean concentration of 3.16 µg/kg. There are two values detected above 10 µg/kg. Total chlordanes were reported at concentrations between 1 and 10 µg/kg in 26 results, and the remaining 23 results were reported at concentrations less than 1 µg/kg (Table 5.2-17). No subsurface samples were collected from the vicinity of the Zidell facility.

Study Area Reach (RM 1.9 to 11.8)

Total chlordanes were reported in 648 of 1,214 subsurface samples (frequency of detection 53 percent) within the Study Area. Concentrations reported range from 0.0390 J to 2,330J µg/kg (Table 5.2-2), with a mean concentration of 19.5 µg/kg. The spatial distribution of total chlordanes in subsurface sediment is presented on Figure 5.2-20 and Maps 5.2-23a-o.

Areas in the eastern nearshore zone with total chlordanes in subsurface sediment reported at concentrations greater than 10 µg/kg were observed at RM 2.2, 3.8, 5.5, Swan Island Lagoon, and at RM 11E (Figure 5.2-20 and Maps 5.2-23a-o). The highest total chlordanes concentration of 490 µg/kg in subsurface sediment reported in the eastern nearshore zone was at Station C092 at RM 3.8. Mean total chlordanes concentrations by river mile are 2.26 µg/kg at RM 2–3; 31.2 µg/kg at RM 3–4; 4.67 µg/kg at RM 5–6; 15.5 µg/kg in Swan Island Lagoon; and 23.5 µg/kg for RM 11–11.8 (Table 5.2-3).

Total chlordanes concentrations greater than 10 µg/kg in the western nearshore zone from RM 4.5 through 9. The highest reported total chlordanes concentration of 2,330J µg/kg in subsurface sediments was reported at RM 8.8 at Station C455 in the interval of 30–152 cm bml (Figure 5.2-20). Mean concentrations by river mile are 5.79 µg/kg for RM 4–5; 17.2 µg/kg at RM 5–6; 18.9 µg/kg at RM 6–7; 68.5 µg/kg at RM 7–8; and 61.4 µg/kg at RM 8–9 (Table 5.2-8).

The highest reported concentrations of total chlordanes in subsurface sediment in the navigation channel were observed at RM 6.5, 10.3, and 11.3. Total chlordanes concentrations at RM 6.5 appear associated with observed contamination in the western nearshore zone (Map 5.2-23g). Concentrations at RM 11.3 are potentially associated the contamination noted at RM 11E (Maps 5.2-23n,o). Mean concentrations are 6.59 µg/kg at RM 6–7; 2.83 µg/kg for RM 10–11; and 7.82 at RM 11–11.8 (Table 5.2-6).

Total chlordanes were reported at a concentration greater than 1,000 µg/kg in one result, 19 were between 100 and 1,000 µg/kg, 67 results were reported at concentrations between 10 and 100 µg/kg, 316 were between 1 and 10 µg/kg, and 245 results were reported at concentrations less than 1 µg/kg (Table 5.2-9).

Downstream Reach (RM 0 to 1.9)

Total chlordanes were reported in 5 of 26 subsurface sediment samples within the Downstream Reach (frequency of detection 19 percent). Concentrations reported range from 0.75 NJ to 2.2 NJ µg/kg (Table 5.2-20). Four results were reported at a concentration greater than 1 µg/kg, and 1 sample was reported at less than 1 µg/kg, with a mean in of 1.5 µg/kg (Tables 5.2-21).

5.2.7.4 Total Chlordanes Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas with the Study Area Reach. There are insufficient data to compare surface and subsurface concentrations in the Upriver Reach. The mean total chlordanes surface sediment concentration in this reach is 0.391 µg/kg (Table 5.2-11).

Within the Downtown Reach, the mean total chlordanes concentration in surface and subsurface sediments is 1.29 and 3.16 µg/kg, respectively (Tables 5.2-15a and 5.2-16a).

Within the Study Area, total chlordanes concentrations are greater in the subsurface sediments. The mean concentration in surface and subsurface sediments is 5.03 and 19.5 µg/kg, respectively (Tables 5.2-1 and 5.2-2). As shown on Figure 5.2-21, mean concentrations are greater in the nearshore areas than in the navigation channel, and the western nearshore zone is greater than the eastern nearshore zone.

In the eastern nearshore zone, total chlordanes concentrations are greater in subsurface than in surface sediment in all river miles except RM 10 to 11. In the western nearshore zone, subsurface sediment concentrations are greater in all river miles except RM 1.9 to 3. Within the navigation channel total chlordanes concentrations in subsurface sediment are greater than the surface sediment concentrations except from RM 1.9 to RM 4. Areas where the highest total chlordanes concentrations are observed generally align between surface and subsurface sediment.

Within the Downstream Reach, the mean total chlordanes concentrations are 0.812 µg/kg and 1.5 µg/kg in surface and subsurface sediment, respectively (Tables 5.2-19 and 5.2-20).

5.2.8 Aldrin and Dieldrin in Sediment

The insecticides aldrin and dieldrin, have similar chemical structures and are discussed together here because aldrin readily undergoes biotic and abiotic transformation to dieldrin. However, because aldrin is not converted to dieldrin under anaerobic conditions, it is unlikely that aldrin is converted to dieldrin in sediments, but may do so within other media that will be discussed in subsequent sections.

The distribution of aldrin and dieldrin concentrations at each surface sediment sampling station throughout the Study Area is depicted on Maps 5.2-25 and 5.2-27; concentrations with depth at subsurface stations are depicted on Maps 5.2-26a-o and 5.2-28a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two results is presented on these maps; all subsurface samples are presented.

Figures 5.2-22 and 5.2-23 present scatter plots of the aldrin data set for surface and subsurface sediment in the Study Area, respectively. Figures 5.2-25 and 5.2-26 present scatter plots of the dieldrin data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-1).

The summary statistics for aldrin and dieldrin in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present aldrin and dieldrin results as orders of magnitude (e.g., <1, 1–10, 10–100, 100–1,000, etc.) for only detected values and for combined detected and non-detected values. Finally, a histogram of average surface and subsurface sediment values by river mile and for the entire Study Area is presented in Figures 5.2-24 (for aldrin) and 5.2-27 (for dieldrin).

Data sets for the Upriver Reach, Downtown Reach, and Downstream Reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown Reach surface sediment samples are presented in Maps 5.2-29 and 5.2-30. Summary statistics for surface and subsurface sediment within the Upriver Reach are shown in Tables 5.2-11 and 5.2-12; the number of data points by order of magnitude is provided in Tables 5.2-13 (detects only) and 5.2-14 (detects and non-detects). Summary statistics for surface and subsurface sediment within the Downtown Reach are shown in Tables 5.2-15 and 5.2-16; the number of data points by order of magnitude is provided in Tables 5.2-17 (detects only) and 5.2-18 (detects and non-detects). Summary statistics for surface and subsurface sediment within the Downstream Reach are shown in

Tables 5.2-19 and 5.2-2; the number of data points by order of magnitude is provided in Tables 5.2-21 (detects only) and 5.2-22 (detects and non-detects).

5.2.8.1 Aldrin and Dieldrin Data Sets

The data set for aldrin consists of 1,146 surface and 1,272 subsurface samples from the Study Area, 77 surface and 3 subsurface samples from the Upriver Reach, 145 surface and 94 subsurface samples from the Downtown Reach, and 25 surface and 26 subsurface samples from the Downstream Reach.

The data set for dieldrin consists of 1,190 surface and 1,208 subsurface samples from the Study Area, 77 surface and 3 subsurface samples from the Upriver Reach, 145 surface and 94 subsurface samples from the Downtown Reach, and 25 surface and 26 subsurface samples from the Downstream Reach.

There were high detection limits for several aldrin and dieldrin results within the Study Area (Figures 5.2-22 and 5.2-23 for aldrin, Figures 5.2-25 and 5.2-26 for dieldrin); thus, the majority of this discussion, as for other contaminants, will focus on the detected values only since meaningful conclusions cannot be drawn from the elevated non-detect values.

5.2.8.2 Aldrin and Dieldrin in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Aldrin was reported in 7 of 77 surface sediment samples within the Upriver Reach (detection frequency of 9 percent). Concentrations reported range from 0.17 J to 0.55 µg/kg (Tables 5.2-11 and 5.2-13) with a mean concentration of 0.334 µg/kg.

Dieldrin was reported in 10 of 77 surface sediment samples (frequency of detection 13 percent). Concentrations reported range from 0.092 NJ to 0.4 µg/kg (Tables 5.2-11 and 5.2-13), with a mean concentration of 0.209 µg/kg.

Downtown Reach (RM 11.8 to 15.3)

Aldrin was reported in 22 of 145 surface sediment samples within the Downtown Reach (frequency of detection 15 percent). Concentrations reported range from 0.0735 J to 0.7 NJ µg/kg (Tables 5.2-15a and 5.2-17), with a mean concentration of 0.262 µg/kg.

Dieldrin was reported in 14 of 145 surface sediment within the Downtown Reach (frequency of detection 10 percent). Concentrations reported range from 0.042 J to 1.1 µg/kg (Tables 5.2-15a and 5.2-17), with a mean concentration of 0.266 µg/kg.

In 2011, a remedial action was taken at the Zidell facility under DEQ authority. Table 5.2-15 presents the data statistics for the Downtown Reach excluding the Zidell data and for the Zidell data removed from the Downtown data set. None of the aldrin or dieldrin data was excluded from the Downtown Reach.

Study Area Reach (RM 1.9 to 11.8)

Aldrin was reported in 268 of 1,146 surface sediment samples within the Study Area (frequency of detection 23 percent). Concentrations reported range from 0.00333 J to 691 J µg/kg (Table 5.2-1), with a mean concentration of 4.89 µg/kg. The spatial distribution of aldrin in surface sediment in the Study Area is presented on Figure 5.2-22.

Dieldrin was reported in 252 of 1,190 surface sediment samples within the Study Area (frequency of detection 21 percent). Concentrations reported range from 0.00834 J to 356 J µg/kg (Table 5.2-1), with a mean concentration of 2.56 µg/kg. The spatial distribution of dieldrin in surface sediment is presented on Figure 5.2-25.

Aldrin was not reported at a concentration greater than 10 µg/kg in surface sediment within the eastern nearshore zone (Figure 5.2-22). Areas with reported concentrations greater than 1 µg/kg are noted in the eastern nearshore zone from RM 2 to 4, 5.8 to 6.2, and in Swan Island Lagoon. The highest reported concentration in surface sediment of 6 µg/kg aldrin in the eastern nearshore zone was at Station PSY01 in Swan Island Lagoon. Mean aldrin concentrations (Table 5.2-3) for these areas in the eastern nearshore zone are 0.872 µg/kg at RM 1.9–3; 0.517 µg/kg at RM 3–4; 0.899 µg/kg at RM 5–6; and 1.03 µg/kg in Swan Island Lagoon.

Detected concentrations of dieldrin greater than 10 µg/kg in surface sediment were observed only in Swan Island Lagoon (Figure 5.2-25). Concentrations greater than 1 µg/kg were observed in the same pattern as aldrin, with the addition of RM 11 to 11.8 in the eastern nearshore zone. The highest reported concentration of dieldrin in surface sediment in the eastern nearshore zone (22 µg/kg) is located at Station M0201 in Swan Island Lagoon. Mean concentrations of dieldrin (Table 5.2-3) in these areas in the eastern nearshore zone are 0.826 µg/kg at RM 1.9–3; 0.205 µg/kg at RM 3–4; 1.17 µg/kg at RM 5–6; 4.35 µg/kg in Swan Island Lagoon; and 4.38 µg/kg at RM 11–11.8.

Aldrin at concentrations greater than 10 µg/kg was reported in the western nearshore zone from RM 6.8 through 7 and at RM 8.8. Reported concentrations greater than 100 µg/kg were observed at RM 7.3 and 8.8 (Figure 5.2-22). The maximum concentration of aldrin in surface sediment (691 J µg/kg) is located at Station G355 (RM 7.3W). Concentrations greater than 1 µg/kg were observed from RM 3 through 10. Mean concentrations by river mile in the western nearshore zone are 0.552 µg/kg at RM 3–4; 0.595 at RM 4–5; 1.01 µg/kg at RM 5–6; 3.41 µg/kg at RM 6–7; 40.4 µg/kg at RM 7–8; 13.5 µg/kg at RM 8–9; and 1.0 µg/kg at RM 9–10 (Table 5.2-7).

Dieldrin was reported at concentrations greater than 10 µg/kg in the western nearshore zone at RM 6.3, 7.3, and 8.3–8.8. Reported concentrations greater than 100 µg/kg were noted at RM 8.8 (Figure 5.2-25). The maximum reported concentration of dieldrin (356 J µg/kg) is located at Station G453 (RM 8.8W). Concentrations greater than 1 µg/kg were observed at RM 3.3, 5.5–9.8, and at 11.3. Mean concentrations by river mile in the western nearshore are 0.294 µg/kg at RM 3–4; 0.427 µg/kg at RM 5–6; 1.83 µg/kg at RM 6–7; 2.85 µg/kg at RM 7–8; 28.7 µg/kg at RM 8–9; and 2.50 µg/kg at RM 11–11.8 (Table 5.2-7).

Neither aldrin nor dieldrin was detected in the navigation channel at concentrations greater than 10 µg/kg (Figures 5.2-22 and 5.2-25). Concentrations of aldrin greater than 1 µg/kg were observed from RM 2 to 3, 5 to 7.5, and at 9.3. Mean concentrations (Table 5.2-5) in these areas are 0.738 µg/kg at RM 1.9–3; 1.15 µg/kg at RM 5–6. 0.806 µg/kg at RM 6–7; and 0.688 µg/kg at RM 9–10. Dieldrin was reported at concentrations greater than 1 µg/kg at RM 5.6 and RM 6.4. Mean concentrations in these areas are 0.711 at RM 5–6 and 0.494 µg/kg at RM 6–7.

Aldrin was reported at a concentration greater than 100 µg/kg in surface sediment in 2 results, 12 detected results were between 10 and 100 µg/kg, 67 results were between 1 and 10 µg/kg, and 187 (70 percent) were reported at concentrations less than 1 µg/kg (Table 5.2-9).

A single dieldrin result was reported at a concentrations greater than 100 µg/kg in surface sediment, 6 were between 10 and 100 µg/kg, 33 were reported at concentrations between 1 and 10 µg/kg, and 212 samples (84 percent) were less than 1 µg/kg (Table 5.2-9).

Downstream Reach (RM 0 to 1.9)

Aldrin was reported in 3 of 25 surface sediment samples within the Downstream Reach (frequency of detection 12 percent). Concentrations reported range from 0.37 J to 0.4J µg/kg (Tables 5.2-19 and 5.2-21), with a mean of 0.39 µg/kg. Dieldrin was reported in 1 of 25 surface sediment samples at a concentration of 0.069 J µg/kg.

5.2.8.3 Aldrin and Dieldrin in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

Aldrin and dieldrin were not detected in the three subsurface sediment samples collected in the Upriver Reach. Detection limits ranged up to 0.2 µg/kg for aldrin and 0.036 µg/kg for dieldrin (Table 5.2-12).

Downtown Reach (RM 11.8 to 15.3)

Aldrin was reported in 8 of 94 subsurface sediment samples within the Downtown Reach (frequency of detection 9 percent). Concentrations reported range from 0.079 J to 1.7 µg/kg (Table 5.2-15), with a mean concentration of 0.414 µg/kg. With the exception of the 1.7 µg/kg result, all reported values were less than 1 µg/kg (Table 5.2-17).

Dieldrin was reported in 4 of 94 subsurface sediment samples (frequency of detection 4 percent); concentrations reported range from 0.2 9J to 16 J µg/kg (Table 5.2-15, Table 5.2-17), with a mean concentration of 7.06 µg/kg.

In 2011, a remedial action was taken at the Zidell facility under DEQ authority. Table 5.2-15 presents the data statistics for the Downtown Reach excluding the Zidell data and for the Zidell data removed from the Downtown data set. None of the aldrin or dieldrin data was excluded from the Downtown Reach.

Study Area Reach (RM 1.9 to 11.8)

Aldrin was reported in 135 of 1,172 subsurface sediment samples within the Study Area (frequency of detection 12 percent). Concentrations reported range from 0.110 J µg/kg to 1,340J µg/kg (Table 5.2-1), with a mean of 23.3 µg/kg. The spatial distribution of aldrin in subsurface sediment within the Study Area is presented on Figure 5.2-23.

Dieldrin was reported in 77 of 1,208 subsurface sediment samples within the Study Area (frequency of detection 6 percent). Concentrations reported range from 0.0380 NJ to 100J µg/kg (Table 5.2-1), with a mean of 3.60 µg/kg. The spatial distribution of dieldrin in subsurface sediment also is presented on Figure 5.2-26.

The maximum reported concentration (3.81 NJ µg/kg) of aldrin in subsurface sediment in the eastern nearshore zone was at Station C019-1 at RM 2.3E. Concentrations greater than 1 µg/kg were observed from RM 1.9 to 6.7 and at RM 11.2 (Figure 5.2-23). Mean concentrations by river mile are 0.989 µg/kg at RM 1.9–3; 0.667 µg/kg at RM 3–4; 0.717 µg/kg at RM 4–5; 0.920 µg/kg at RM 5–6; 0.561 µg/kg at RM 6–7; and 1.80 µg/kg at RM 11–11.8 (Table 5.2-4).

Dieldrin was reported in subsurface sediment at a maximum concentration of 100 µg/kg in the eastern nearshore zone at RM 3.7E (Station C092; 30–152 cm bml) at the head of the International Terminals Slip (Figure 5.2-26; Table 5.2-4).

The maximum reported aldrin concentration in subsurface sediment (1,340 J µg/kg) in the western nearshore zone was observed at RM 7.4 at Station C356, 136–256 cm bml (Figure 5.2-23). Aldrin concentrations in sediment greater than 1 µg/kg were observed from RM 4.5 to 8.8, concentrations greater than 10 µg/kg were observed from RM 6.1 through 8.8, and concentrations greater than 100 µg/kg were reported at RM 6.1 and 8.8 (Figure 5.2-23). Mean concentrations in these areas are 0.851 µg/kg at RM 4–5; 1.90 µg/kg at RM 5–6; 28.9 µg/kg at RM 6–7; 72.5 µg/kg at RM 7–8; and 67.9 µg/kg at RM 8–9 (Table 5.2-8). Reported dieldrin concentrations greater than 10 µg/kg in the western nearshore zone occur between RM 6 and 8.8 (Figure 5.2-26). Mean concentrations in these areas are 4.52 µg/kg at RM 6–7; 3.95 µg/kg at RM 7–8; and 17.3 µg/kg at RM 8–9 (Table 5.2-8).

Within the navigation channel, aldrin concentrations greater than 10 µg/kg were noted at RM 6.4, and sediment concentrations greater than 1 µg/kg were detected from RM 6 to 7 and at RM 10.3 (Figure 5.2-23). The maximum reported aldrin concentration (44J µg/kg) within the navigation channel was observed at core Station C299 (RM 6.4 near the west bank). Mean concentrations in these areas are 12.9 µg/kg at RM 6–7, and 0.667 µg/kg at RM 10–11 (Table 5.2-6). Dieldrin was reported at a concentration greater than 10 µg/kg in only one sample located within the navigation channel at Station WR-CD-40 (13 µg/kg) near RM 11.3. Concentrations above 1 µg/kg were also reported in cores collected at RM 3.5, 6.1, and 11.2. Mean concentrations in these areas are 0.750 µg/kg at RM 3–4; 3.00 µg/kg at RM 6–7; and 5.55 µg/kg at RM 11–11.8 (Table 5.2-6).

Downstream Reach (RM 0 to 1.9)

Aldrin was reported in 3 of 26 subsurface sediment samples within the Downstream Reach (frequency of detection 12 percent). Reported concentrations range from 0.2 J to 2.8 NJ µg/kg (Table 5.2-19), with a mean of 1.2 µg/kg. Dieldrin was not reported within the Downstream Reach.

5.2.8.4 Aldrin and Dieldrin Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentration by reach and also by subareas within the Study Area Reach. There are insufficient data to compare surface and subsurface concentrations in the Upriver Reach. Mean concentrations in surface sediment are 0.334 and 0.209 µg/kg for aldrin and dieldrin, respectively.

Within the Downtown Reach, mean aldrin and dieldrin concentrations were greater in subsurface versus surface sediment. Mean surface and subsurface concentrations were 0.262 and 0.414 µg/kg for aldrin, and 0.266 and 7.06 µg/kg for dieldrin, respectively.

Within the Study Area, aldrin and dieldrin concentrations are also generally greater in subsurface than in surface sediments. Study Area-wide, mean surface and subsurface concentrations are 4.89 and 23.3 µg/kg for aldrin and 2.56 and 3.60 µg/kg for dieldrin. Exceptions to this general trend are noted in the western nearshore zone at RM 9–10 where the mean aldrin concentration is greater in surface sediment, at RM 8–9 where the mean dieldrin concentration is greater in surface sediment, and at RM11–11.8 where both aldrin and dieldrin mean concentrations are greater in surface sediment (Figures 5.2-24 and 27).

In Swan Island Lagoon, the mean aldrin and dieldrin concentrations are greatest in surface sediment. Mean dieldrin concentrations in surface sediment are greater at RM 1.9E–3E and 5E–6E. Within the navigation channel, mean aldrin and dieldrin concentrations in surface sediment concentrations are greater than in subsurface sediment.

Insufficient data are available in the Downstream Reach to allow meaningful comparisons between surface and subsurface sediment concentrations.

5.2.9 Arsenic in Sediment

The distribution of arsenic concentrations at each surface sediment sampling station throughout the Study Area is depicted on Map 5.2-31; concentrations with depth at subsurface stations are depicted on Maps 5.2-32a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps, all subsurface samples are presented.

Figures 5.2-28 and 5.2-29 present scatter plots of the arsenic data set for surface and subsurface sediment in the Study Area, respectively. The scatter plots present the data in three panels segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-1).

Summary statistics for arsenic in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2, respectively. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Tables 5.2-9 and 5.2-10 present arsenic data as orders of magnitude (e.g., <1, 1–10, 10–100, 100–1,000, etc.) for only detected values and for combined detected and non-detected values. Finally, a histogram of average surface and subsurface sediment values by river mile and for the entire Study Area is presented in Figure 5.2-30.

Data sets for the Upriver Reach, Downtown Reach, and Downstream Reach are only presented in statistical tables and order of magnitude tables. Additionally, the Downtown Reach surface sediment samples are presented in Map 5.2-33. Summary statistics for surface and subsurface sediment within the Upriver Reach are shown in Tables 5.2-11 and 5.2-12; the number of data points by order of magnitude is provided in Tables 5.2-13 (detects only) and 5.2-14 (detects and non-detects). Summary statistics for surface and subsurface sediment within the Downtown Reach are shown in Tables 5.2-15 and 5.2-16; the number of data points by order of magnitude is provided in Tables 5.2-17 (detects only) and 5.2-18 (detects and non-detects). Summary statistics for surface and subsurface sediment within the Downstream Reach are shown in Tables 5.2-19 and 5.2-20; the number of data points by order of magnitude is provided in Tables 5.2-21 (detects only) and 5.2-22 (detects and non-detects).

5.2.9.1 Arsenic Data Set

Arsenic results includes 1,551 surface and 1,553 subsurface samples from within the Study Area, 77 surface and 3 subsurface samples from the Upriver Reach, 233 surface and 178 subsurface samples from the Downtown Reach, and 25 surface and 26 subsurface samples from the Downstream Reach.

5.2.9.2 Arsenic in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Arsenic was reported in 73 of 77 surface sediment samples within the Upriver Reach (frequency of detection 95 percent). Concentrations reported range from 1.9 J to 5.29 mg/kg (Table 5.2-11), with a mean of 2.94 mg/kg.

Downtown Reach (RM 11.8 to 15.3)

Arsenic was reported in 201 of 233 surface sediment within the Downtown Reach (frequency of detection 86 percent). Concentrations reported range from 1.07 to 126 mg/kg (Table 5.2-15), with a mean concentration of 6.2 mg/kg. The spatial distribution of arsenic within the Downtown Reach is presented on Map 5.2-33. The majority of results are less than 5 mg/kg. Localized areas with concentrations greater than 25 mg/kg were observed at RM 13 under the Hawthorne Bridge and on the western shore between the Marquam and Ross Island bridges.

One result was reported at a concentration greater than 100 mg/kg, 17 results were between 10 and 100 mg/kg, 183 results (91 percent of the detected data set) were less than 10 mg/kg, and no detected results were reported at concentrations less than 1 mg/kg (Table 5.2-17).

In 2011, a remedial action was taken at the Zidell facility under DEQ authority. Table 5.2-15 presents the data statistics for the Downtown Reach excluding the Zidell data and for the Zidell data removed from the Downtown data set. Arsenic was reported in 74 surface sediment samples within the Zidell action area, and reported concentrations range from 1.29 to 78 J mg/kg (Table 5.2-15). The mean arsenic concentration for this area is 11.2 mg/kg. When the data for the Zidell facility is removed from the downtown data set (Table 5.2-15), the range of arsenic concentrations in surface sediment is from 1.07 to 126 mg/kg with a mean concentration of 4.71 mg/kg.

Study Area Reach (RM 1.9 to 11.8)

Arsenic was reported in 1,426 of 1,551 surface sediment samples within the Study Area (frequency of detection 92 percent). Concentrations reported range from 0.700 to 132 mg/kg (Table 5.2-1), with a mean of 4.86 mg/kg. The spatial distribution of arsenic concentrations within the Study Area is presented on Figure 5.2-28.

Within the eastern nearshore zone, sediment concentrations approaching or greater than 100 mg/kg were observed at RM 2.3, 5.6, and 7.2 (Figure 5.2-28). Areas where concentrations are greater than 10 mg/kg occur near RM 5.5, 7, and in Swan Island Lagoon (Figure 5.2-28, Map 5.2-31). The highest surface concentration detected in the eastern nearshore zone (132 mg/kg) was found at Station RB08 at RM 2.3. Mean concentrations (Table 5.2-3) for these areas are 5.76 mg/kg at RM 1.9–3; 7.05 mg/kg at RM 5–6; 7.16 mg/kg at RM 7–8; and 5.87 mg/kg in Swan Island Lagoon.

Areas in the western nearshore zone where arsenic concentrations exceed 10 mg/kg occur from RM 3.5 through 7, 8.3 to 9.2, and at 10.2. Three localized areas where reported concentrations are greater than 50 mg/kg are located at RM 6.8, 8.6 (80 mg/kg at Station A2GS10), and RM 10.2 (Figure 5.2-28). Mean concentrations in these areas in the western nearshore zone are 4.86 mg/kg at RM 3–4; 4.10 mg/kg at RM 4–5; 4.12 mg/kg at RM 5–6; 5.99 mg/kg at RM 6–7; 9.17 mg/kg at RM 8–9; 5.79 mg/kg at RM 9–10; and 9.96 mg/kg at RM 10–11 (Table 5.2-7).

There were no reported arsenic concentrations in surface sediment exceeding 10 mg/kg in the navigation channel.

Within the Study Area, arsenic was reported in surface sediment at a concentration greater than 100 mg/kg in 2 results, 57 were between 10 and 100 mg/kg, 1,364 (96 percent of the detected results) were reported at concentrations between 1 and 10 mg/kg, and 3 were reported at concentrations less than 1 mg/kg (Table 5.2-9).

Downstream Reach (RM 0 to 1.9)

Arsenic was reported in all 25 surface sediment samples within the Downstream Reach. Concentrations reported range from 0.6 J to 6.4 mg/kg (Table 5.2-19). One result was reported at a concentration less than 1 mg/kg, and the remaining 24 results were between 1 and 10 mg/kg (Table 5.2-21). The mean arsenic concentration in this reach is 3.7 mg/kg.

5.2.9.3 Arsenic in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

Arsenic was analyzed and reported in only three subsurface samples between RM 15.4 and 16. Concentrations reported range from 2.37 to 2.45 mg/kg.

Downtown Reach (RM 11.8 to 15.3)

Arsenic was reported in 168 of 178 subsurface sediment samples within the Downtown Reach (frequency of detection 94 percent). Concentrations reported from 0.57 to 7.5 mg/kg (Table 5.2-16), with a mean of 2.96 mg/kg. The majority of the results (165 samples) were reported at concentrations between 1 and 10 mg/kg, and the remaining 3 results were reported at concentrations less than 1 mg/kg (Table 5.2-17).

In 2011, a remedial action was taken at the Zidell facility under DEQ authority. Table 5.2-16 presents the data statistics for the Downtown Reach excluding the Zidell data and for the Zidell data removed from the Downtown data set. Arsenic was analyzed in 30 subsurface sediment samples within the Zidell action area. Reported concentrations range from 2 to 7.5 mg/kg, with a mean concentration in this area of 3.5 mg/kg. When the data for the Zidell facility are removed from the downtown data set (Table 5.2-16), the range of reported concentrations in subsurface sediment is 0.57 to 7.19 mg/kg, with a mean of 2.89 mg/kg.

Study Area Reach (RM 1.9 to 11.8)

Arsenic was reported in 1,489 of 1,553 subsurface samples within the Study Area (frequency of detection 96 percent). Concentrations reported range from 0.500 J to 51.4 mg/kg (Table 5.2-2) with a mean of 4.08 mg/kg. The spatial distribution of reported arsenic concentrations in subsurface sediment is presented on Figure 5.2-29 and Maps 5.2-32a-o).

Within the eastern nearshore zone, arsenic concentrations in subsurface sediment exhibit a different pattern than observed in surface sediment (Figure 5.2-30).

Concentrations greater than 10 mg/kg occur at RM 3.6, 4.6, 5.6, 8.5, 11.3, and in Swan Island Lagoon (Figure 5.2-29 and Maps 5.2-32a-o). Single points are noted at RM 6.7 and 7.4. The highest reported subsurface concentration of 51 mg/kg was observed in the interval of 150–236 cm bml at Station C708, near the mouth of Swan Island Lagoon. Mean concentrations in these eastern nearshore areas are 3.61 mg/kg at RM 3–4; 3.47 mg/kg at RM 4–5; 5.37 mg/kg at RM 5–6; 4.11 mg/kg at RM 6–7; 4.11 mg/kg at RM 7–8; 11.5 mg/kg at RM 8–9; 4.81 mg/kg in Swan Island Lagoon; and 4.73 mg/kg at RM 11–11.8 (Table 5.2-3).

Arsenic concentrations greater than 10 mg/kg were reported in the western nearshore zone from RM 3.6 through 9.2, most prominently between RM 8.6 and 9.2 (Figure 5.2-29). The maximum reported value in the western nearshore zone was 43.3 mg/kg at Station HA-38 at RM 9.0. Mean concentrations in this area are 6.07 mg/kg at RM 3–4; 4.04 mg/kg at RM 4–5; 4.25 mg/kg at RM 5–6; 3.61 mg/kg at RM 6–7; 4.34 mg/kg at RM 7–8; 5.67 mg/kg at RM 8–9; and 8.11 mg/kg at RM 9–10 (Table 5.2-8).

Only three results from within the navigation channel were reported at a concentration greater than 10 mg/kg, at RM 7.9, 10.3, and 11.5. Within these areas, mean arsenic concentrations were 4.18 mg/kg at RM 7–8; 4.02 mg/kg at RM 10–11; and 3.03 mg/kg at RM 11–11.8 (Table 5.2-6).

Of the reported arsenic concentrations in subsurface sediment, 45 results were greater than 10 mg/kg, 1,433 results (96 percent of the reported results) were between 1 and 10 mg/kg, and 11 were reported at concentrations less than 1 mg/kg (Table 5.2-9).

Downstream Reach (RM 0 to 1.9)

Arsenic was reported in all 26 subsurface sediment samples collected within the Downstream Reach, with reported concentrations ranging from 0.6 J to 13 mg/kg (Table 5.2-20). Table 5.2-21 shows that there is one sample detected at a concentration greater than 10 mg/kg. The majority of the samples (24 samples; 92 percent) were detected at concentrations between 1 and 10 mg/kg. Only one sample was detected at a concentration less than 1 mg/kg. The mean arsenic concentration in this reach is 4.06 mg/kg.

5.2.9.4 Arsenic Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach, and also by subareas with the Study Area Reach. There are insufficient data to allow for a meaningful comparison of surface and subsurface concentrations in the Upriver Reach. The mean arsenic surface sediment concentration in this reach is 2.94 mg/kg (Table 5.2-11).

Surface sediment concentrations in the Downtown Reach were greater than the subsurface concentrations, suggesting that there may be ongoing sources in this reach. The mean surface concentration is 6.2 mg/kg, while the mean subsurface sediment concentration is 2.96 mg/kg (Tables 5.2-15a and 5.2-16a).

Arsenic concentrations are also generally greater in the surface sediments than in subsurface sediments within the Study Area as a whole. The mean surface sediment concentration is 4.86 mg/kg, and the mean subsurface sediment concentration is 4.08 mg/kg (Tables 5.2-1 and 5.2-2). Figure 5.2-30 shows that mean concentrations are greater in the nearshore areas than in the navigation channel, and the western nearshore zone is slightly greater than the eastern nearshore zone. It also shows that concentrations are generally greater in the surface sediment than in subsurface sediment.

In the eastern nearshore zone, surface sediment concentrations are greater than subsurface sediment in all river mile zones except RM 8 to 9 and 11 to 11.8. In the western nearshore zone, subsurface sediment concentrations are greater than surface sediment in all river miles except RM 4 to 5, 6 to 7, 8 to 9, and possibly 10 to 11. The subsurface sediment concentrations in the navigation channel are generally the same as the surface sediment concentrations.

Areas where subsurface sediment concentrations are elevated do not align with the locations where surface sediment concentrations are elevated. The most prominent areas are RM 8 to 9 in the eastern nearshore zone, and RM 8 to 9 and 10 to 11 in the western nearshore zones. Additional areas where elevated concentrations do not align are RM 1.9 to 3, 5 to 6, 7 to 8, and Swan Island lagoon in the eastern nearshore zone, and RM 3 to 4, 6 to 7, and 8 to 10 in the western nearshore zone (Figure 5.2-30).

The surface sediment concentrations in the Downstream Reach were greater than subsurface concentrations. The mean surface concentration is 3.7 mg/kg, while the mean subsurface concentration is 4.06 mg/kg (Tables 5.2-19 and 5.2-20).

5.2.10 Chromium in Sediment

The distribution of chromium concentrations in surface sediment throughout the Study Area is depicted on Map 5.2-34, and subsurface results are depicted on Maps 5.2-35a-o. If more than one sample was analyzed from the same surface sediment location, the greater of the two results is presented; all subsurface samples are presented.

Scatter plots of chromium data from within the Study Area are presented on Figures 5.2-31 and 5.2-32, respectively, for surface and subsurface sediment segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-1).

Summary statistics for surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Chromium results by orders of magnitude (<1, 1–10, 10–100, 100–1,000, etc.) are presented for detected values in Table 5.2-9, and for combined detected and non-detected results in Table 5.2-10. A histogram of average surface and subsurface sediment values by river mile and for the Study Area is presented on Figure 5.2-33.

Results for the Upriver, Downtown, and Downstream Reaches are presented in statistical tables and order of magnitude tables. Additionally, surface sediment results for the Downtown Reach are presented in Map 5.2-36. Summary statistics for surface and subsurface sediment results within the Upriver Reach are shown in Tables 5.2-11 and 5.2-12, respectively. Results by order of magnitude are provided in Tables 5.2-13 (detects only) and 5.2-14 (detects and non-detects). Summary statistics for surface and subsurface sediment results within the Downtown Reach are shown in Tables 5.2-15 and 5.2-16, respectively; the number of results by order of magnitude is provided in Tables 5.2-17 (detects only) and 5.2-18 (detects and non-detects). Summary statistics for surface and subsurface sediment within the Downstream Reach are shown in Tables 5.2-19 and 5.2-20, respectively; the number of results by order of magnitude is provided in Tables 5.2-21 (detects only) and 5.2-22 (detects and non-detects).

5.2.10.1 Chromium Data Set

The Study Area chromium data set consists of 1,536 surface and 1,530 subsurface samples. The Upriver data set consists of 66 surface and 3 subsurface samples, the Downtown data set consists of 265 samples and 178 subsurface samples, and the Downstream data set consists of 25 surface and 26 subsurface samples.

5.2.10.2 Chromium in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Chromium was reported in all 66 surface sediment samples within the Upriver Reach. Reported concentrations ranged from 11.9 J to 40.5 mg/kg (Table 5.2-11). All results were between 10 and 100 mg/kg, with a mean of 23.1 mg/kg (Table 5.2-13).

Downtown Reach (RM 11.8 to 15.3)

Chromium was reported in all 265 surface sediment samples within the Downtown Reach. Concentrations reported ranged from 1.24 J to 758 J mg/kg (Table 5.2-15), with a mean concentration of 34.6 mg/kg. The majority of the results are less than 50 mg/kg, with concentrations greater than 50 mg/kg present at RM 13 on the western shore downstream of the Hawthorne Bridge and on the western shore between the Marquam and Ross Island bridges (Map 5.2-36).

Within the Downtown Reach, 14 results (5 percent of data set) were reported at concentrations greater than 100 mg/kg, 218 results (82 percent) were between 10 and 100 mg/kg, and 33 results (12 percent) were reported at concentrations less than 10 mg/kg (Tables 5.2-17 and 5.2-18).

In 2011, a remedial action was taken at the Zidell facility under DEQ authority. Table 5.2-15 presents the data statistics for the Downtown Reach excluding the Zidell data and for the Zidell data removed from the Downtown data set. Chromium was reported in 110 surface sediment samples within the Zidell action area, and concentrations range from 1.24 J to 758 J mg/kg (Table 5.2-15), with a mean of 56.0 mg/kg. When the data for the Zidell facility are removed from the Downtown data set (Table 5.2-15), the range of chromium concentrations in surface sediment is from 4.51 to 189 mg/kg, with a mean concentration of 19.4 mg/kg.

Study Area Reach (RM 1.9 to 11.8)

Chromium was reported in 1,530 of 1,536 surface sediment samples within the Study Area (detection frequency of 99.6 percent). Reported concentrations ranged from 4.07 J to 819 J mg/kg (Table 5.2-1), with a mean of 35.4 mg/kg.

Concentrations greater than 100 mg/kg are present in the eastern nearshore zone at RM 2.1–2.4, 3.7–4.4, 5.6–5.9, and in Swan Island Lagoon (Figure 5.2-31 and Map 5.2-34). Single results greater than 100 mg/kg are present at RM 7.2 and 11. The maximum reported concentration in the eastern nearshore zone (819 J mg/kg) was found at Station RB06 at RM 2.2. Mean concentrations (Table 5.2-3) in these areas in the eastern nearshore zone are 99.9 mg/kg at RM 1.9–3; 30.7 mg/kg at RM 3–4; 29.3 mg/kg at RM 4–5; 45.1 mg/kg at RM 5–6; 34.9 mg/kg at RM 7–8; 35.4 mg/kg in Swan Island Lagoon; and 37.7 mg/kg at RM 11–11.8.

Reported concentrations in the western nearshore zone greater than 100 mg/kg are located at RM 6–6.1, 6.8–6.9, and 8.8–9.2 (Figure 5.2-31). The maximum reported concentration of chromium in surface sediment of 774 mg/kg was found at Station 19A01 (RM 8.4W). Mean concentrations in these areas are 38.8 mg/kg at RM 6-7; 34.8 mg/kg at RM 7–8; 46.9 mg/kg at RM 8–9; and 39.1 mg/kg at RM 9–10 (Table 5.2-7). All chromium results from the navigation channel were less than 100 mg/kg.

Thirty-nine results were reported at concentrations greater than 100 mg/kg, 1,466 results (96 percent) were reported at concentrations between 10 and 100 mg/kg, and the remaining 25 results were reported at concentrations less than 10 mg/kg (Table 5.2-9).

Downstream Reach (RM 0 to 1.9)

Chromium was reported in all 25 surface sediment samples within the Downstream Reach. Reported concentrations range from 10.4 J to 42.2 mg/kg (Tables 5.2-19 and 5.2-21), with a mean concentration of 24.7 mg/kg.

5.2.10.3 Chromium in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

Chromium concentrations were analyzed in only three subsurface samples between RM 15.4 and 16. The samples were all detected at levels ranging from 19.7 to 23.4 mg/kg; the average concentration for this reach is 21.2 mg/kg.

Downtown Reach (RM 11.8 to 15.3)

Chromium was reported in 174 of 178 subsurface sediment samples within the Downtown Reach. Concentrations reported ranged from 4.56 to 143 mg/kg (Table 5.2-16a), with a mean of 22.2 mg/kg. Table 5.2-17 shows that only one result was reported at a concentration greater than 100 mg/kg, 161 results (93 percent of reported results) were reported at concentrations between 1 and 10 mg/kg, 12 results were reported at concentrations less than 1 mg/kg.

In 2011, a remedial action was taken at the Zidell facility under DEQ authority. Table 5.2-16 presents the data statistics for the Downtown Reach excluding the Zidell data and for the Zidell data removed from the Downtown data set. Chromium was reported in 30 subsurface sediment samples within the Zidell action area. Concentrations reported ranged from 14 to 143 mg/kg, with a mean of 36 mg/kg. When data from the Zidell facility are excluded from the downtown data set, reported chromium concentrations in subsurface sediment ranged from 4.56 to 71.7 mg/kg, with a mean of 19.4 mg/kg.

Study Area Reach (RM 1.9 to 11.8)

Chromium was reported in 1,524 of 1,530 subsurface samples. Reported concentrations ranged from 6.41 J to 464 mg/kg (Table 5.2-2), with a mean of 28.8 mg/kg. The distribution of reported chromium concentrations in subsurface sediment within the Study Area is shown on Figure 5.2-32.

Concentrations greater than 100 mg/kg were observed within the eastern nearshore zone at RM 2.2–2.4, 5–6, and in Swan Island Lagoon (Figure 5.2-32 and Maps 5.2-35a-o). The highest reported subsurface concentration in the eastern nearshore zone (249 mg/kg) was found at Station C207-1 near RM 5.6. Mean concentrations in these areas are 30.5 mg/kg at RM 1.9–3; 56.0 mg/kg at RM 5–6; and 31.0 mg/kg in Swan Island Lagoon (Table 5.2-3).

Reported chromium concentrations greater than 100 mg/kg are present in the western nearshore zone at RM 6.1, 7.4, and 8.8–9.2 (Figure 5.2-32). The maximum subsurface concentration (464 mg/kg) was found at Station HA-42 (46–61 cm bml) at RM 9.1. Mean concentrations in these western nearshore areas are 30.3 mg/kg at RM 6–7; 32.3 mg/kg at RM 7–8; 35.2 mg/kg for RM 8–9; and 60.5 mg/kg for RM 9–10 (Table 5.2-8).

Within the navigation channel, chromium greater than 100 mg/kg was reported at RM 6.4 and 11.3. Mean concentrations for these areas are 22.9 mg/kg at RM 6–7 and 21.5 mg/kg at RM 11–11.8 (Table 5.2-6).

Fourteen results were reported at concentrations greater than 100 mg/kg, 1,452 results were between 10 and 100 mg/kg, and 58 results are composed of concentrations less than 10 mg/kg (Table 5.2-9).

Downstream Reach (RM 0 to 1.9)

Chromium was reported in all 26 subsurface sediment samples collected within the Downstream Reach. Concentrations reported ranged from 6.6 to 33.8 mg/kg (Tables 5.2-20 and 5.2-21), with a mean of 23.2 mg/kg.

5.2.10.4 Chromium Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas with the Study Area Reach. There are insufficient data to compare surface and subsurface concentrations in the Upriver Reach.

Within the Downtown Reach, chromium concentrations are greater in surface sediment than in subsurface sediment. The mean surface concentration is 34.6 mg/kg, while the mean subsurface sediment concentration is 22.2 mg/kg (Tables 5.2-15a and 5.2-16a).

Within the Study Area, chromium concentrations are also generally greater in the surface sediments than in subsurface sediments as a whole. Mean concentrations are 35.4 mg/kg in surface and 28.8 mg/kg subsurface sediment (Tables 5.2-1 and 5.2-2, Figure 5.2-33). Mean concentrations are greater in the nearshore areas than in the navigation channel.

Within the eastern nearshore zone, concentrations in surface sediment are greater than in subsurface sediment in all river miles except RM 5–7 and 8–9. Within the western nearshore zone, chromium concentrations in subsurface sediment are greater than in surface sediment in all river miles except RM 9–10 and 11–11.8. Within the navigation channel, surface and subsurface sediment concentrations are generally comparable. The highest concentrations of chromium in subsurface sediment align with areas where surface sediment concentrations are greatest.

Within the Downstream Reach, concentrations in surface sediment are generally greater than in subsurface sediment. The mean surface concentration is 24.7 mg/kg, while the mean subsurface concentration is 23.2 mg/kg (Tables 5.2-19 and 5.2-20).

5.2.11 Copper in Sediment

The distribution of copper concentrations throughout the Study Area is depicted on Map 5.2-37. Reported concentrations with depth at subsurface stations are depicted on Maps 5.2-38a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two samples is presented on these maps; all subsurface samples are presented. Scatter plots of the copper data set for surface and subsurface sediment in the Study Area are presented on Figures 5.2-34 and 5.2-35, respectively, segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-1).

Summary statistics for copper in surface and subsurface sediment within the Study Area are shown in Tables 5.2-1 and 5.2-2. Summary statistics for surface and subsurface sediment within the eastern nearshore, navigation channel, and western nearshore zones are presented in Tables 5.2-3 and 5.2-4, Tables 5.2-5 and 5.2-6, and Tables 5.2-7 and 5.2-8, respectively. Copper results by orders of magnitude (e.g., <1, 1–10, 10–100, 100–1,000, etc.) are presented in Table 5.2-9 (detected results only) and Table 5.2-10 (combined detected and non-detected results). Finally, a histogram of average surface and subsurface sediment values by river mile and for the entire Study Area is presented in Figure 5.2-36.

Data for the Upriver, Downtown, and Downstream Reaches are only presented in statistical tables and order of magnitude tables. Additionally, surface sediment data for the Downtown Reach are presented in Map 5.2-39. Summary statistics for surface and subsurface sediment within the Upriver Reach are shown in Tables 5.2-11 and 5.2-12; the number of results by order of magnitude is provided in Tables 5.2-13 (detect only) and 5.2-14 (detect and non-detect). Summary statistics for surface and subsurface sediment within the Downtown Reach are shown in Tables 5.2-15 and 5.2-16; the number of data points by order of magnitude is provided in Tables 5.2-17 (detect only) and 5.2-18 (detect and non-detect). Summary statistics for surface and subsurface sediment within the Downstream Reach are shown in Tables 5.2-19 and 5.2-20; the number of data points by order of magnitude is provided in Tables 5.2-21 (detect only) and 5.2-22 (detect and non-detect).

5.2.11.1 Copper Data Set

Copper data for the Study Area data consists of 1,552 surface and 1,541 subsurface samples. The Upriver data set includes 72 surface and 3 subsurface samples, the downtown data set consists of 269 surface and 178 subsurface samples, and the downstream data set consists of 25 surface samples and 26 subsurface samples.

5.2.11.2 Copper in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Copper was reported in all 72 surface sediment samples within the Upriver Reach. Concentrations reported with detected concentrations ranged from 10.5 J m to 50.9 mg/kg, with a mean of 24.6 mg/kg (Table 5.2-11). All detected values were between 10 and 100 mg/kg (Table 5.2-13).

Downtown Reach (RM 11.8 to 15.3)

Copper was reported in 264 of 269 surface sediment samples within the Downtown Reach. Concentrations reported ranged from 5.51 to 2,150 J mg/kg, with a mean of 98.6 mg/kg (Table 5.2-15). The distribution of copper concentrations in surface sediment within the Downtown Reach is presented on Map 5.2-39. Reported concentrations are generally less than 30 mg/kg, although areas with concentrations greater than 60 mg/kg are noted at RM 13 on the western shore under the Hawthorne Bridge and on the western shore between the Marquam and Ross Island bridges.

Within the Downtown Reach, 7 results were reported at concentrations greater than 1,000 mg/kg, 29 were reported at concentrations between 100 and 1,000 mg/kg, 222 results (84 percent) were reported at concentrations between 10 and 100 mg/kg, and 6 results were reported at concentrations less than 10 mg/kg (Tables 5.2-17 and 5.2-18).

In 2011, a remedial action was taken at the Zidell facility under DEQ authority. Table 5.2-15 presents the data statistics for the Downtown Reach excluding the Zidell data and for the Zidell data removed from the Downtown data set. Copper was reported in 110 surface sediment samples within the Zidell action area. Reported concentrations ranged from 5.51 to 2,150 J mg/kg (Table 5.2-15), with a mean of 195 mg/kg. When the data for the Zidell facility are excluded from the downtown data set, reported copper concentrations in surface sediment range from 8.39 to 366 mg/kg, with a mean of 32.6 mg/kg (Table 5.2-15).

Study Area Reach (RM 1.9 to 11.8)

Copper was reported in 1,548 of 1,552 surface sediment samples. Concentrations reported ranged from 6.19 J to 2,830 mg/kg, with a mean of 60.8 mg/kg (Table 5.2-1). The distribution of concentrations in surface sediment is presented on Figure 5.2-34.

Copper in surface sediment at concentrations greater than 100 mg/kg in the eastern nearshore zone is present at RM 2.1–2.4, 3.7–4, 5.5–6.1, Swan Island Lagoon, and RM 11.1–11.3 (Figure 5.2-34 and Map 5.2-37). Single results greater than 100 mg/kg are present at RM 6.6, 7.2, and 9.9. Mean concentrations (Table 5.2-3) in these eastern nearshore areas are 42.0 mg/kg at RM 1.9–3; 38.0 mg/kg at RM 3–4; 135 mg/kg at RM 5–6; 53.6 mg/kg at RM 6–7; 53.0 mg/kg at RM 7–8; 122 mg/kg in Swan Island Lagoon; 31.6 mg/kg at RM 9–10; and 161 mg/kg at RM 11–11.8. The highest reported concentration of 2,830 mg/kg copper was reported at RM 11.2 (Station UG01).

Areas where copper concentrations are reported greater than 100 mg/kg in the western nearshore zone are present from RM 4.3 through 10.4, and in particular at RM 4.3–4.7, 5.6–6.1, 6.8–7.4, 8.3–9.2, and 10.2–10.4 (Figure 5.2-34). The maximum reported concentration in the western nearshore zone of 1,370 mg/kg was found at Station HA-43 (RM 9.2). Mean concentrations in these areas are 39.8 mg/kg at RM 4–5; 50.7 mg/kg at RM 5–6; 46.9 mg/kg at RM 6–7; 41.4 mg/kg at RM 7–8; 102 mg/kg at RM 8–9; 110 mg/kg at RM 9–10; and 164 mg/kg at RM 10–11 (Table 5.2-7).

Within the navigation channel, the highest reported copper concentrations are located at RM 5.5, 7.9, and 10.3–10.4. Reported concentrations at RM 5.5 and 7.9 appear to be associated with results observed in the eastern nearshore area, while the results RM 10.3–10.4 appear to be associated with observed concentrations in the western nearshore area (Map 5.2-37). The mean concentrations for these areas are 30.1 mg/kg at RM 5–6; 49.3 mg/kg at RM 7–8; 62.0 mg/kg in Swan Island Lagoon; and 39.7 mg/kg at RM 10–11 (Table 5.2-5).

Within the Study Area, copper was reported at concentrations greater than 1,000 mg/kg in 4 results, 144 results were greater than 100 mg/kg, 1,392 results (90 percent of the detected results) were reported at concentrations between 10 and 100 mg/kg, and 8 results were reported at concentrations less than 10 mg/kg (Table 5.2-9).

Downstream Reach (RM 0 to 1.9)

Copper was reported in all 25 surface sediment samples within the Downstream Reach (detection frequency of 100 percent), with concentrations ranging from 8 to 45.7 mg/kg

(Table 5.2-19). Table 5.2-21 shows that 23 samples are measured at concentrations between 10 and 100 mg/kg and 2 samples are measured at concentration between 1 and 10 mg/kg. There were no samples were detected at concentrations less than 1 mg/kg. The mean copper concentration in this reach is 25.5 mg/kg.

5.2.11.3 Copper in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

Only three subsurface sediment samples were analyzed for copper in the Upriver Reach, all between RM 15.4 and 16. Reported concentrations range from 26 to 33 mg/kg, with a mean of 28.6 mg/kg.

Downtown Reach (RM 11.8 to 15.3)

Copper was reported in all 178 subsurface sediment samples within the Downtown Reach. Concentrations reported range from 9.48 to 1,050 mg/kg, with a mean of 46.3 mg/kg (Table 5.2-16). One result was reported at a concentration greater than 1,000 mg/kg, 8 were reported at concentrations between 100 and 1,000 mg/kg, 167 results were reported at concentrations between 10 and 100 mg/kg, and 2 results were reported at concentrations less than 10 mg/kg (Table 5.2-17).

In 2011, a remedial action was taken at the Zidell facility under DEQ authority. Table 5.2-16 presents the data statistics for the Downtown Reach excluding the Zidell data and for the Zidell data removed from the Downtown data set. Copper was reported in 30 subsurface sediment samples within the Zidell action area. Concentrations reported range from 14 to 1,050 mg/kg, with a mean of 82.1 mg/kg. Excluding the data from the Zidell site, reported concentrations range from 9.48 to 457 mg/kg, with a mean of 39.0 mg/kg (Table 5.2-16).

Study Area Reach (RM 1.9 to 11.8)

Within the Study Area, copper was reported in all 1,541 subsurface samples. Concentrations reported range from 9.42 J to 3,290 mg/kg, with a mean of 55.2 mg/kg (Table 5.2-2). The distribution of concentrations in subsurface sediments is presented on Figure 5.2-35 and Maps 5.2-38a-o.

The subsurface sediment has elevated concentrations in generally the same areas identified in the surface sediment within the eastern nearshore zone (Figure 5.2-35). The maximum subsurface copper concentration (3,290 mg/kg) was found at Station C384 (30–128 cm bml), at the mouth of Swan Island Lagoon. Concentrations greater than 100 mg/kg are noted at RM 3.6, 4.4–4.6, 5.6, 6.1–6.7, 7.4, in Swan Island Lagoon, RM 8.4–8.8, and 11.3 (Figure 5.2-35 and Maps 5.2-38a-o). Mean copper concentrations in these areas in the eastern nearshore zone are 35.6 mg/kg at RM 3–4; 30.2 mg/kg at RM 4–5; 56.9 mg/kg at RM 5–6; 70.0 mg/kg at RM 6–7; 48.3 mg/kg at RM 7–8; 128 mg/kg at RM 8–9; and 145 mg/kg in Swan Island Lagoon (Table 5.2-4).

Within the western nearshore zone, copper concentrations exceeding 100 mg/kg are present from RM 4.1 through 9.2 (Figure 5.2-35 and Maps 5.2-38a-o). The maximum reported subsurface concentration of 1,990 mg/kg in the western nearshore zone was found at Station HA-42 (46–61 cm bml) at RM 9.1. Mean concentrations in these areas are 48.0 mg/kg at RM 4–5; 33.9 mg/kg at RM 5–6; 39.4 mg/kg at RM 6–7; 42.6 mg/kg at RM 7–8; 59.8 mg/kg at RM 8–9; and 229 mg/kg at RM 9–10 (Table 5.2-8).

There are two areas with results greater than 100 mg/kg in the navigation channel, located at RM 7.6–8 and 10.2–10.3. The results at RM 7.6–8 may be associated with concentrations observed in the eastern nearshore zone, and the results at RM 10.2–10.3 may be collocated with elevated concentrations the western nearshore zone (Maps 5.2-38a-o). The mean concentrations for these areas are 68.7 mg/kg at RM 7–8, and 51.4 mg/kg at RM 10–11 (Table 5.2-6).

Table 5.2-9 shows that a total of 6 results in subsurface sediment were reported at concentrations greater than 1,000 mg/kg, 78 results were between 100 and 1,000 mg/kg, 1,456 results were reported at concentrations between 10 and 100 mg/kg, and 1 result was than 10 mg/kg.

Downstream Reach (RM 0 to 1.9)

Copper was reported in all 26 subsurface sediment samples within the Downstream Reach. Concentrations reported range from 8.9 to 43.6 mg/kg, with a mean of 25.7 mg/kg (Table 5.2-20). Table 5.2-21 shows that the majority of samples (a total of 24 of the 26 results) were reported at a concentration greater than 10 mg/kg, and 2 samples were reported at a concentration less than 10 mg/kg.

5.2.11.4 Copper Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas with the Study Area Reach. There are insufficient data to compare surface and subsurface concentrations in the Upriver Reach.

The mean surface sediment concentration of 98.6 mg/kg in the Downtown Reach is greater than the subsurface mean of 46.3 mg/kg (Table 5.2-15a). However, when the Zidell data are excluded, the mean surface and subsurface sediment concentrations are similar at 32.6 and 39.0 mg/kg, respectively (Table 5.2-15).

Copper concentrations in the subsurface sediments are generally comparable to the concentration in the surface sediments within the Study Area as a whole (Figure 5.2-36). The mean surface sediment concentration is 60.8 mg/kg, and the mean subsurface sediment concentration is 55.2 mg/kg (Tables 5.2-1 and 5.2-2).

In the eastern nearshore zone, mean concentrations in surface sediment are greater than in subsurface sediment in all river mile zones except RM 6–7, 8–9, and in Swan Island Lagoon. In the western nearshore zone, mean concentrations in subsurface sediment are greater than in surface sediment in all river miles except RM 5–7 and 8–9. Within the navigation channel, mean subsurface and surface sediment concentrations are comparable, with the mean subsurface sediment concentrations slightly greater in all river miles except RM 1.9–3 and 4–7. Areas with the highest copper concentrations in subsurface sediment generally align with the locations where surface sediment concentrations are greatest, although there are more areas with only elevated surface or elevated subsurface sediment concentrations (Figure 5.2-36). Mean surface and subsurface concentrations in the Downstream Reach are 25.5 and 25.7 mg/kg, respectively (Tables 5.2-19 and 5.2-20).

5.2.12 Zinc in Sediment

The distribution of zinc concentrations throughout the Study Area is presented on Map 5.2-40. Reported concentrations with depth are depicted on Maps 5.2-41a-o. If more than one sample was analyzed at the same surface sediment location, the greater of the two results is presented; all subsurface results are presented. Scatter plots of zinc results in the Study Area are presented on Figures 5.2-37 and 5.2-38 for surface and subsurface sediment, respectively, segregated by the eastern nearshore, navigational channel, and western nearshore zones (Map 5.2-1).

Summary statistics are presented in Tables 5.2-1 and 5.2-2 for surface and subsurface sediment, respectively, within the Study Area, and in Tables 5.2-3 and 5.2-4 for the eastern nearshore zone, Table 5.2-5 and 5.2-6 for the navigation channel, and Tables 5.2-7 and 5.2-8 for the western nearshore zone. Results by order of magnitude (e.g., <1, 1–10, 10–100, 100–1,000, etc.) are presented in Table 5.2-9 for detected results only and Table 5.2-10 for combined detected and non-detected values. Finally, a histogram of average surface and subsurface sediment values by river mile and for the entire Study Area is presented in Figure 5.2-39.

Data sets for the Upriver, Downtown, and Downstream Reaches are only presented in statistical tables and order of magnitude tables. The Downtown Reach surface sediment results are also presented in Map 5.2-42. Summary statistics for surface and subsurface sediment within the Upriver Reach are shown in Tables 5.2-11 and 5.2-12, respectively. The number of results by order of magnitude is provided in Tables 5.2-13 (detects only) and 5.2-14 (detects and non-detects). Summary statistics of results within the Downtown Reach are shown in Tables 5.2-15 and 5.2-16 for surface and subsurface sediment, respectively. The number of results by order of magnitude is provided in Tables 5.2-17 (detects only) and 5.2-18 (detects and non-detects). Summary statistics of results within the Downstream Reach are shown in Tables 5.2-19 and 5.2-20 for surface and subsurface sediment, respectively. The number of results by order of magnitude is provided in Tables 5.2-21 (detects only) and 5.2-22 (detects and non-detects).

5.2.12.1 Zinc Data Set

The zinc data set consists of 1,581 surface and 1,581 subsurface samples from the Study Area, 72 surface and 3 subsurface samples from the Upriver Reach, 269 surface and 178 subsurface samples from the Downtown Reach, and 25 surface and 26 subsurface samples Downstream Reach.

5.2.12.2 Zinc in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

Zinc was reported in all 72 surface sediment samples within the Upriver Reach. Concentrations reported range from 41.1 J to 165 mg/kg, with a mean of 75.2 mg/kg (Table 5.2-11) Four results were reported at concentrations greater than 100 mg/kg, and the remaining 68 data points were between 10 and 100 mg/kg (Table 5.2-13).

Downtown Reach (RM 11.8 to 15.3)

Zinc was reported in all 269 surface sediment samples within the Downtown Reach. Concentrations reported range from 3.27 J to 6,480 J mg/kg, with a mean of 294 mg/kg (Table 5.2-15). The distribution of surface sediment results in the Downtown Reach is presented on Map 5.2-42. The majority of results are less than 300 mg/kg. Concentrations greater than 600 mg/kg were reported at RM 13 on the western shore under the Hawthorne Bridge and on the western shore between the Marquam and Ross Island bridges.

Concentrations greater than 1,000 mg/kg were reported in 15 results, 102 results were reported at concentrations between 100 to 1,000 mg/kg, 151 results were reported at concentrations between 10 and 100 mg/kg, and 1 result was reported at a concentration less than 10 mg/kg (Table 5.2-17 and 5.2-18).

In 2011, a remedial action was taken at the Zidell facility under DEQ authority. Table 5.2-15 presents the data statistics for the Downtown reach excluding the Zidell data and for the Zidell data removed from the Downtown data set.. Zinc was reported in all 110 surface sediment samples within the Zidell action area. Concentrations reported range from 3.27 J to 6,480 J mg/kg, with a mean of 555 mg/kg (Table 5.2-15). With the Zidell facility data excluded from the downtown data set, reported zinc concentrations range from 22.8 to 1,450 mg/kg, with a mean of 113 mg/kg (Table 5.2-15).

Study Area Reach (RM 1.9 to 11.8)

Zinc was reported in all 1,581 surface sediment samples within the Study Area. Concentrations reported range from 3.68 J to 4,220 mg/kg, with a mean of 154 mg/kg (Table 5.2-1). The distribution of reported zinc concentrations within the Study Area is shown on Figure 5.2-37.

Concentrations greater than 300 mg/kg were reported in the eastern nearshore zone at RM 2.1–2.3, 3.7–4.6, 5.6–5.9, and in Swan Island Lagoon (Figure 5.2-37 and Map 5.2-40). Single exceedances greater than 300 mg/kg were reported at RM 6.7, 7.2, 9.9, and 11.3. The highest zinc concentration in the eastern nearshore zone of 2,050 mg/kg was reported at RM 4.6 (Station T4-UP13). Mean zinc concentrations in these areas in the eastern nearshore zone are 190 mg/kg at RM 1.9–3; 159 mg/kg at RM 3–4; 234 mg/kg at RM 4–5E; 192 mg/kg RM 5–6; 123 mg/kg at RM 6—7; 114 mg/kg at RM 7–8; 227 mg/kg in Swan Island Lagoon; 97.1 mg/kg at RM 9–10; and 132 mg/kg at RM 11–11.8 (Table 5.2-3).

Concentrations greater than 300 mg/kg were reported in the western nearshore zone from at RM 6.1, 6.7–6.8, 8.1–9.3, 9.6–9.7, and 10.3–10.4 (Figure 5.2-37). The maximum reported concentration of zinc in surface sediment in the Study Area of 4,220 mg/kg was detected at Station HA-43 at RM 9.2W. Mean concentrations for these western nearshore areas are 150 mg/kg at RM 6–7; 290 mg/kg at RM 8–9; 394 mg/kg at RM 9–10; and 212 mg/kg at RM 10–11 (Table 5.2-7). All reported concentrations of zinc in the navigation channel were less than 300 mg/kg.

Within the Study Area, zinc was reported at concentrations greater than 1,000 mg/kg in 15 results, 914 results were reported at concentrations greater than 100 mg/kg, 650 results were reported at concentrations between 10 and 100 mg/kg, and 2 results were reported at concentrations less than 10 mg/kg (Table 5.2-9).

Downstream Reach (RM 0 to 1.9)

Zinc was reported in all 25 surface sediment samples within the Downstream Reach. Concentrations reported ranged from 47.6 to 188 mg/kg, with a mean of 98.2 mg/kg (Table 5.2-19). Concentrations greater than 100 mg/kg were reported in 12 results, and 13 results were reported at concentrations between 10 and 100 mg/kg (Table 5.2-21).

5.2.12.3 Zinc in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

Zinc was analyzed in only three subsurface samples between RM 15.4 and 16 and reported at concentrations ranging from 65.8 to 119 mg/kg, with a mean of 87.6 mg/kg.

Downtown Reach (RM 11.8 to 15.3)

Zinc was reported in all 178 subsurface sediment samples from within the Downtown Reach. Concentrations reported ranged from 21.4 to 11,100 J mg/kg, with a mean of 379 mg/kg (Table 5.2-16). One result was reported at a concentration greater than 10,000 mg/kg, 9 results were reported at concentrations between 1,000 and 10,000 mg/kg, 77 results were reported at concentrations between 100 and 1,000 mg/kg, and 91 results were reported at concentrations between 10 and 100 mg/kg (Table 5.2-17).

Table 5.2-16 presents data statistics for the Downtown Reach with the Zidell data excluded and for the Zidell data removed from the Downtown data set. Zinc was reported in 30 samples within the Zidell action area at concentrations ranging from 41 to 2,270 mg/kg, with a mean of 207 mg/kg. With the Zidell data excluded from the downtown data, reported zinc concentrations in subsurface sediment range from 21.4 to 11,100 J mg/kg, with a mean of 414 mg/kg (Table 5.2-16).

Study Area Reach (RM 1.9 to 11.8)

Zinc was analyzed and detected in 1,581 samples within the Study Area (100 percent detection frequency) with concentrations ranging from 24.0 to 9,000 mg/kg (Table 5.2-2) and a mean concentration of 147 mg/kg. Similar to surface sediment, zinc concentrations in the subsurface also varied within the Study Area (Figure 5.2-38; Maps 5.2-41a-o).

The subsurface sediment has elevated concentrations in generally the same areas identified in the surface sediment within the eastern nearshore zone (Figure 5.2-38). Concentrations greater than 300 mg/kg are noted at RM 2.3, 3.7, 4.2–4.6, 5.6, 6.7, in Swan Island Lagoon, 8.4–8.6, and 11.1 (Figure 5.2-39 and Maps 5.2-41a-o). The maximum subsurface zinc concentration in the eastern nearshore zone (1,930 mg/kg) was found at Station C384 (30–128 cm bml), at the mouth of Swan Island Lagoon. Mean zinc concentrations (Table 5.2-3) for these areas in the eastern nearshore zone are 131 mg/kg at RM 1.9–3; 149 mg/kg at RM 3–4; 155 mg/kg at RM 4–5; 171 mg/kg at RM 5–6; 133 mg/kg at RM 6–7; 291 mg/kg at RM 8– 9; 181 mg/kg in Swan Island Lagoon; and 159 mg/kg at RM 11–11.8.

The western nearshore zone has detected zinc concentrations that exceed 300 mg/kg from RM 6.7 through 9.2 with clusters noted at RM 6.7, 7.6–7.7, and 8.3–9.2 (Figure 5.2-38 and Maps 5.2-41a-o). The maximum subsurface concentration (9,000mg/kg) was found at Station HA-42 (15–61 cm bml) at RM 9.1W. Mean concentrations (Table 5.2-8) for these areas in the western nearshore zone are 126 mg/kg at RM 6–7; 131 mg/kg at RM 7–8; 190 mg/kg at RM 8–9; and 792 mg/kg at RM 9–10.

There is one peak with samples greater than 300 mg/kg in the navigation channel zone located at RM 10.2–10.3 with two individual samples exceeding 300 mg/kg at RM 6.4 and RM 7.9. The elevated concentrations within the navigation channel are near elevated concentrations the western nearshore zone. The mean concentrations for these areas are 102 mg/kg at RM 6–7; 125 mg/kg at RM 7–8; and 127 mg/kg at RM 10–11 (Table 5.2-6).

Table 5.2-9 shows that there are 6 subsurface samples greater than 1,000 mg/kg, and 834 samples ranging between 100 and 1,000 mg/kg. Subsurface sediment values greater than 100 mg/kg account for 53 percent of the detected data set. The remainder of the detected data set (741 samples; 47 percent) is between 10 and 100 mg/kg. There were no samples detected at concentrations less than 10 mg/kg.

Downstream Reach (RM 0 to 1.9)

Zinc was analyzed and detected in 26 subsurface sediment samples within the Downstream Reach (detection frequency of 100 percent), with concentrations ranging from 10.8 to 244 mg/kg (Table 5.2-20). Table 5.2-21 shows that approximately half of samples (14 samples) were detected at a concentration greater than 100 mg/kg, and half the samples (12 samples) were detected at a concentration less than 100 mg/kg. There were no samples were detected at concentrations less than 10 mg/kg. The mean zinc concentration in this reach is 118 mg/kg.

5.2.12.4 Zinc Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships are examined by comparing surface and subsurface concentrations by reach and also by subareas with the Study Area Reach. There are insufficient data to compare surface and subsurface concentrations in the Upriver Reach. The mean zinc surface sediment concentration in this reach is 75 mg/kg (Table 5.2-11).

The surface sediment concentrations in the Downtown Reach were lower than the subsurface concentrations. The mean surface concentration is 294 mg/kg, while the mean subsurface sediment concentration is 379 mg/kg (Tables 5.2-15a and 5.2-16a).

Zinc concentrations are generally similar in the surface sediments and subsurface sediments within the Study Area as a whole. The mean surface sediment concentration is 154 mg/kg, and the mean subsurface sediment concentration is 147 mg/kg (Tables 5.2-1 and 5.2-2). Areas where subsurface sediment concentrations are elevated generally align with the locations where surface sediment concentrations are elevated. Figure 5.2-39 shows that mean concentrations are generally greater in the nearshore areas than in the navigation channel, and the western nearshore zone has slightly greater subsurface concentrations than the eastern nearshore zone, while the eastern nearshore zone has higher surface concentrations.

In the eastern nearshore zone, surface sediment concentrations are slightly greater than subsurface sediment in all river mile zones except RM 6–9 and 10–11.8. In the western nearshore zone, subsurface sediment concentrations are greater than surface sediment in all river miles except RM 3– 4, 6–7, and 8–9. With the exception of RM 8E–9E and 9W–10W, the subsurface concentrations are slightly greater than the surface concentrations in these areas.

The subsurface sediment concentrations in the navigation channel are generally the same as the surface sediment concentrations, although the subsurface sediment concentrations are slightly greater in all river miles except RM 5–6.

The subsurface sediment concentrations in the Downstream Reach were greater than surface concentrations. The mean surface concentration is 98.2 mg/kg, while the mean subsurface concentration is 118 mg/kg (Tables 5.2-19 and 5.2-20).

5.2.13 Tributyltin Ion in Sediment

Several data presentations for the surface and subsurface TBT data sets for the Study Area are provided for this discussion. There are maps, scatter plots, statistical summary tables, order of magnitude tables, and a histogram of mean surface and subsurface sediment concentrations by river mile. The distribution of TBT concentrations at each surface sampling station throughout the Study Area is depicted in Map 5.2-43, concentrations with depth at subsurface stations are depicted in Maps 5.2-44a–o.

The data for TBT in the Study Area are presented on scatter plots on Figures 5.2-40 and 5.2-41 for surface and subsurface sediment, respectively. These plots present the data in three panels segregated by the eastern nearshore, navigation channel, and western nearshore zones (Map 5.2-1).

Summary statistics for TBT within the Study Area are shown in Tables 5.2-1 and 5.2-2 for surface and subsurface sediment, respectively. Summary statistics for surface and subsurface sediment and are presented in Tables 5.2-3 and 5.2-4 within the eastern nearshore, Tables 5.2-5 and 5.2-6 in the navigation channel, and Tables 5.2-7 and 5.2-8 for the western nearshore zones. TBT data are presented as orders of magnitude (e.g., <1, 1–10, 10–100, 100–1,000, etc.) in Table 5.2-9 for detected values, and Table 5.2-10 for combined detected and non-detected values. Finally a histogram of average surface and subsurface sediment values for TBT by river mile and for the entire Study Area is presented in Figure 5.2-42.

Data sets for the Upriver, Downtown, and Downstream Reaches are only presented in statistical tables and order of magnitude tables. Additionally, surface sediment results for the Downtown Reach are presented on Map 5.2-45. Summary statistics for surface and subsurface sediment within the Upriver Reach are shown in Tables 5.2-11 and 5.2-12; number of results by order of magnitude is provided in Tables 5.2-13 (detects only) and 5.2-14 (detects and non-detects). Summary statistics for surface and subsurface sediment within the Downtown Reach are presented in Tables 5.2-15 and 5.2-16; number of results by order of magnitude is provided in Tables 5.2-17 (detects only) and 5.2-18 (detects and non-detects). Summary statistics for surface and subsurface sediment with the Downstream Reach are presented in Tables 5.2-19 and 5.2-20; number of results by order of magnitude is provided in Tables 5.2-21 (detects only) and 5.2-22 (detects and non-detects).

5.2.13.1 Tributyltin Ion Data Set

Sampling for TBT analysis was based on a biased approach at locations near known or suspected sources. As a result, there are relatively fewer data points for these analytes in the RI sediment database than for other chemicals. This is particularly true in areas away from suspected sources, such as the navigation channel. However, areas with known or suspected TBT sources have been sufficiently characterized and the existing TBT data are sufficient for RI purposes.

Within the Study Area, TBT was analyzed in 358 surface and 433 subsurface samples. The upriver data set consists of 8 surface and 3 subsurface samples. The downtown data set is 174 surface and 65 subsurface samples, and the downstream data set is 4 surface and no subsurface samples. The small number of data points for TBT limits the extent to which its distribution may be resolved (Sections 5.2.13.2 and 5.2.13.3) and introduces the need for caution in interpreting the surface to subsurface trends shown by the histograms (Figures 5.2-42).

5.2.13.2 Tributyltin Ion in Surface Sediment

Upriver Reach (RM 15.3 to 28.4)

TBT was reported in 4 of 8 surface sediment samples within the Upriver Reach. Concentrations reported range from 0.72 J to 2.3 µg/kg (Table 5.2-11). Three results were reported at concentrations between 1 and 10 µg/kg, and one result was reported at a concentration less than 1 µg/kg. The mean concentration in this reach is 1.31 µg/kg (Table 5.2-13).

Downtown Reach (RM 11.8 to 15.3)

TBT was reported in 62 of 174 surface sediment samples within the Downtown Reach (frequency of detection 36 percent). Concentrations range from 0.4 J to 1,990 µg/kg, with a mean concentration of 75.6 µg/kg (Table 5.2-15). Results with the highest concentrations are located along the western shoreline (Map 5.2-45).

Tables 5.2-17 shows that there are 2 results reported at concentrations greater than 1,000 µg/kg, 2 results between 100 and 1,000 µg/kg, 12 results were reported at concentrations between 10 and 100 µg/kg, 32 results between 1 and 10 µg/kg, and 14 results were reported at concentrations less than 1 µg/kg.

In 2011, a remedial action was taken at the Zidell facility under DEQ authority. Table 5.2-15 presents the statistics for the Downtown Reach excluding the Zidell data and for the Zidell data removed from the Downtown data set. TBT was reported in 26 of 80 surface sediment samples within the Zidell action area. Concentrations reported range from 1.9 to 1,990 µg/kg, with a mean of 102 µg/kg (Table 5.2-15c). With the Zidell data excluded from the downtown data set, reported TBT concentrations range from 0.4 J to 1,700 J µg/kg, with a mean of 55 µg/kg (Table 5.2-15b).

Study Area Reach (RM 1.9 to 11.8)

TBT was reported in 333 of 358 surface sediment samples within the Study Area. Concentrations reported range from 0.45 J to 47,000 µg/kg, with a mean of 466 µg/kg (Table 5.2-1). The distribution of reported TBT concentrations within the Study Area is presented on Figure 5.2-40 and Map 5.2-43.

Concentrations greater than 1,000 µg/kg in the eastern nearshore zone were reported at RM 3.7, 7.5, and in Swan Island Lagoon. The highest reported surface sediment concentration of 47,000 µg/kg was reported at Station SD12 (RM 3.7, at the head of International Slip). A concentration of 46,000 µg/kg was reported at Station G421 in Swan Island Lagoon. Mean concentrations in these areas are 1,570 µg/kg at RM 3–4; 193 µg/kg at RM 7–8; and 2,340 µg/kg in Swan Island Lagoon (Table 5.2-3).

Within the navigation channel, TBT concentrations greater than 1,000 µg/kg were reported near Swan Island Lagoon (1,800 µg/kg at Station SD124 at RM 7.7; Figure 5.2-40). The mean concentration at RM 7–8 is 373 µg/kg (Table 5.2-5).

A single measurement greater than 1,000 µg/kg was reported at RM 8.8 in the western nearshore zone. The mean concentration at RM 8–9 is 83.8 µg/kg (Table 5.2-7).

Two results were reported at concentrations greater than 10,000 µg/kg, 12 results were between 1,000 and 10,000 µg/kg, 71 results were reported at concentrations between 100 and 1,000 µg/kg, 125 results were between 10 to 100 µg/kg, 108 results between 1 and 10 µg/kg, and 15 results were reported at concentrations less than 1 µg/kg (Tables 5.2-9, Map 5.2-43).

Downstream Reach (RM 0 to 1.9)

TBT was reported in all 4 samples within the Downstream Reach at concentrations between 0.37 J and 1.2 J µg/kg, with a mean of 0.85 µg/kg (Tables 5.2-19, 5.2-21, and 5.2-22).

5.2.13.3 Tributyltin Ion in Subsurface Sediment

Upriver Reach (RM 15.3 to 28.4)

TBT was analyzed in three subsurface sediment samples between RM 15.4 and 16, and was not detected at maximum detection limit of 0.094 µg/kg.

Downtown Reach (RM 11.8 to 15.3)

TBT was reported in 21 of 65 subsurface sediment samples within the Downtown Reach. Concentrations reported range from 0.55 J to 14,000 µg/kg (Table 5.2-15a), with a mean concentration of 1,052 µg/kg.

One result was reported at a concentration greater than 10,000 µg/kg, one each was reported between 1,000 and 10,000 µg/kg and between 100 and 1,000 µg/kg, five results were between 10 and 100 µg/kg, nine were between 1 and 10 µg/kg, and four results were reported at a concentration less than 1 µg/kg (Tables 5.2-17).

In 2011, a remedial action was taken at the Zidell facility under DEQ authority. Table 5.2-16 presents data statistics for the Downtown Reach with the Zidell data excluded and for the Zidell data removed from the Downtown data set. TBT was reported in 13 of 23 subsurface sediment samples within the Zidell action area. Concentrations reported range to a maximum reported value of 14,000 µg/kg, with a mean of 1,697 µg/kg. When the data from the Zidell facility are excluded from the downtown data set, the range of reported concentrations ranges from 0.55 J to 23 µg/kg, with a mean of 4.48 µg/kg (Table 5.2-16).

Study Area Reach (RM 1.9 to 11.8)

TBT was detected in 223 of the 433 subsurface samples analyzed within the Study Area. Concentrations reported range from 0.32J to 90,000 µg/kg, with a mean of 1,410 µg/kg (Table 5.2-2). TBT concentrations in subsurface sediment within the Study Area are presented on Figure 5.2-41 and Maps 5.2-44a-o.

TBT concentrations reported in the eastern nearshore zone at concentrations greater than 1,000 µg/kg are present at RM 7–8 and in Swan Island Lagoon (Figure 5.2-41). A single result of 1,000 µg/kg was reported at RM 5.6. Mean concentration in these areas in are 196 µg/kg at RM 5–6; 1,250 µg/kg at RM 7–8; 13,700 µg/kg at RM 8–9; and 5,380 µg/kg in Swan Island Lagoon (Table 5.2-4).

Within the western nearshore zone there were no reported TBT concentrations greater than 1,000 µg/kg (Figure 5.2-41). Concentrations greater than 1,000 µg/kg were reported in the navigation channel at RM 7.8 and in Swan Island Lagoon (Maps 5.2-44a-o). The highest reported concentrations in subsurface sediment are generally found at the same surface locations where TBT concentrations are greater than 1,000 µg/kg along the eastern nearshore zone (Maps 5.2-44a–o).

Within the Study Area, 8 results were greater than 10,000 µg/kg, 14 were between 1,000 and 10,000 µg/kg, 35 results were reported at concentrations between 100 and 1,000 µg/kg, 88 results were between 10 and 100 µg/kg, 62 were between 1 and 10 µg/kg, and 16 results were reported at concentrations less than 1 µg/kg (Table 5.2-9).

Downstream Reach (RM 0 to 1.9)

TBT was not analyzed in subsurface sediment samples within the Downstream Reach.

5.2.13.4 Tributyltin Ion Surface and Subsurface Sediment Relationships

Surface and subsurface sediment relationships were examined by comparing surface and subsurface concentrations by reach and also by subareas within the Study Area. There are insufficient data to compare surface and subsurface concentrations in the Upriver and Downstream Reaches.

Within the Downtown Reach, the mean TBT concentrations are 74.6 and 1,052 µg/kg in surface and subsurface sediment, respectively. With the Zidell data excluded, this relationship is reversed, and the mean concentrations in surface and subsurface sediment are 55.0 and 4.48 µg/kg, respectively.

Within the Study Area, TBT concentrations are generally greater in the subsurface than in surface sediments. The mean concentrations are 466 and 1,410 µg/kg in surface and subsurface sediment, respectively. Most areas throughout the Study Area Reach lack a strong or consistent vertical concentration gradient, although the majority of the contamination appears in the shallower subsurface samples. This pattern is supported by Maps 5.2-44d-j.

5.3 INDICATOR CONTAMINANTS IN MOBILE SEDIMENT

This section discusses mobile sediment at Portland Harbor by summarizing the sediment trap data collected for this investigation. The sediment trap investigation was designed to capture anticipated spatial and temporal variability of suspended sediment mass, fill data gaps related to the nature and extent of potential sources, and support the preparation of the BERA (Anchor 2006b). The geographic locations of all sediment trap stations are presented on Map 2.1-24.

Discussion of the indicator contaminants addressed in this section focuses primarily on the following elements:

- A description of the data set for each contaminant, including frequency of detection and concentration range
- The sampling locations and periods (sampling quarters) with elevated contaminant concentrations and any apparent spatial or temporal gradients within the data set
- An evaluation of contaminant concentrations found in the Study Area compared to concentrations found at locations outside of the Study Area.

The following subsections present tables, histograms, and other graphical summaries of the data to support discussion and evaluation of the nature and extent of the indicator contaminants in the sediment traps. Additional tabular and graphical summaries of the sediment trap data set are included in Appendix D2.

The chemistry distributions for the sediment traps are depicted graphically in histograms showing indicator contaminant concentrations for each location and grouped by sampling quarter (Figures 5.3-1a-b through 5.3-15a-b). The blank spaces in the histograms within station groups signify that the volume of material collected for the quarter was not sufficient for analysis or the sediment trap was lost. Sample analyses resulting in non-detects are flagged in the histograms to distinguish them from cases where results are not available. Scales for indicator contaminant concentrations (y-axis) were selected to emphasize higher concentrations yet visually distinguish comparatively low concentrations. In some cases, values above scale maximums are labeled with the sample concentration.

Other graphic displays used to assist with data interpretation include two scatter plots (Figures 5.3-16 and 5.3-17) with regression lines to fit the data and accompanying regression equations. Natural log-transformed PCB congener concentrations are regressed on natural log-transformed Aroclor concentrations in Figure 5.3-17 to display the relationship between PCB results obtained using different analytical methods. The relationship between sediment accumulation rates and the percentage of fines (i.e., silt and clay, particles $\leq$62 μm) is shown in a scatter plot of the un-transformed data sets (Figure 5.3-16). Plots of sample grain size distribution are shown in Figures 5.3-18a-b. Line graphs (Figures 5.3-19a-b) are used to display the Willamette River daily discharge hydrograph for the entire sediment trap sampling period, with quarterly sampling periods identified by different colors. This hydrograph also displays average historical daily discharges for a 36-year period (1972–2008). Figures 5.3-20a-b show the quarterly distribution of the daily Willamette River discharge combined with sediment accumulation rates (also depicted in Figures 5.3-21a-b), and percent fines (percent fines values are also depicted in Appendix D2.1, Figure D2.1-22a-b).

5.3.1 Mobile Sediment Data Set

This section focuses on the concentrations of indicator contaminants associated with samples from in-river sediment trap samples collected within the lower Willamette River. Sediment traps were deployed at 16 locations in the lower Willamette River from late 2006 through late 2007 (see Map 2.1-24). Twelve of the locations were within the Study Area between RM 1.9 and 11.5. One sediment trap was deployed just downstream of the Study Area at RM 1.8, two were located just upstream of Ross Island at RM 15.6 and 15.7, and one was located in Multnomah Channel. Paired sediment traps were deployed and maintained on opposite sides of the river at approximately RM 1.9, 6, 11.5, and 15.7. Samples were retrieved quarterly to obtain four quarters (1 year) of data. A total of 52 sediment trap samples were collected and analyzed per the protocols used in Rounds 2A and 2B; some samples were not obtained due to lack of material in the trap or loss of the trap.

In June 2009, seven sediment traps were deployed by the City of Portland between RM 11 and 12.1 (Map 2.1-15ff) to characterize settleable suspended sediments in this area of the river during Quarters 3 and 4 of 2009 (GSI 2010b). A total of 13 samples were collected and analyzed from this sampling event; one sediment trap (ST007) was not recovered during Quarter 4.

The samples were analyzed to measure the sediment trap mass accumulation and concentrations of sediment-bound contaminants that enter the Study Area from upstream sources, contaminant concentrations associated with regional sources within the Study Area, and concentrations of sediment-bound contaminants that migrate downstream from the Study Area. Additional information on the lower Willamette River hydrology, sediment accumulation, and the role of fine sediments provided to aid with interpretation of the chemical data is presented in Figures 5.3-18a-b through 5.3-21a-b. Distributions of the indicator contaminants are shown in Figures 5.3-1a-b through 5.3-15a-b and are summarized in Tables 5.3-1 through 5.3-7.

5.3.2 River Conditions During Sampling Events

Hydrologic data used to assess flow patterns during sampling were obtained from the USGS stream flow station located upstream of the Morrison Bridge (Willamette River at Portland, gage no. 14211720). The stream flows measured during the sampling events are presented in Figures 5.3-19a-b. The highest flows during sampling occurred during Quarter 1 (November and December 2006) of the 2006/2007 sampling event, with a median daily discharge of 79,000 cfs (Figure 5.3-19a). This period was characterized by variable flows, reaching twice the historical average discharge during a number of separate events. Lower than normal discharge periods (up to 60 percent of average) occurred twice during the month of December 2009, only to be followed by higher than normal flows (up to 50 percent of average) in early January 2010. The discharge record for Quarters 2 and 3 of the 2006/2007 (February through August 2007) sampling event (median discharges of 31,000 cfs and 10,000 cfs, respectively) did not demonstrate the variability that characterized Quarter 1 of the 2006/2007 sampling event. In general, sampling during Quarters 2 and 3, and at least a portion of Quarter 4, of the 2006/2007 sampling event, and Quarter 3 of the 2009 sampling event (median discharge of 11,000 cfs), occurred during river flows that were very similar to historical averages. Discharge data from the last half of Quarter 4 of the 2006/2007 sampling event (October 2007 through mid-November 2007) are considered estimates due to uncertainty about the accuracy of the rating curve used at the Portland location for flows less than 20,000 cfs.

5.3.3 Rates of Sediment Accumulation

Net sediment accumulation rates at each station/quarter were calculated from the height of the sediment column in the traps and from the specific gravity and moisture content of the material. Sediment accumulation rates for each sediment trap are shown in Figures 5.3-21a-b. The highest rates of accumulation occurred during Quarter 1 of the 2006/2007 sampling event, with the largest accumulation in the sediment traps placed at RM 11.3 and 15.6 (Figures 5.3-21a-b); sediment accumulation rates were lower in the sediment traps placed downstream of RM 11.3. Because density measurements were only taken during the 2006/2007 sampling event, only those data were used to determine an average density of 1.22 $g/cm^2/day$ to calculate accumulation rates for the 2009 sampling event (Figure 5.3-21b). Traps were lost at stations ST014 (RM 7.5), ST006 (Swan Island Lagoon), and ST016 (RM 9.9) during Quarter 1 of the 2006/2007 sampling event, so information regarding sediment accumulation is not available for these samples.

Medium-coarse silt made up approximately 50 percent of the trapped material during each quarter of the 2006/2007 sampling event, although the highest sediment accumulation rates generally corresponded with a comparatively low percentage of fine material in the sediment traps. Grain size data are only available for one sediment trap sample (ST001) in Quarter 3 of the 2009 sampling event and six sediment traps (ST001 through ST006) in Quarter 4. Figure 5.3-16 shows rates of accumulation as a function of percent fines. Trend lines shown for the data set as a whole ($R^2 = 0.38$), as well as for the individual quarters (R^2 ranging from 0.0063 to 0.79), suggest inverse linear relationships between accumulation rates and percent fines for this data set are weak. TOC showed relatively small differences among samples, with concentrations ranging from 1.1 to 3.5 percent. The majority of the measured TOC values, approximately 75 percent, range between 2 and 3 percent (Appendix D2.1, Figures D2.1-23a-b).

Because sediment trap samples do not constitute temporally discrete samples (i.e., they represent a continuous collection over a 3-month period), river conditions during sampling can only be discussed meaningfully in seasonal terms. Accumulation rates of trapped sediment may have been substantially affected by instantaneous events, such as high water resulting from heavy rainfall, but the impact of these isolated events cannot be quantified based on the existing data or the sampling methodology employed. Further, there were instances in which sediment traps found to contain insufficient accumulated material for analysis were redeployed with the previous quarter's deposited material. In two cases (ST001 Quarter 3, and ST013 Quarter 3), traps retrieved in the following quarter were found to have a shorter column of sediment in them than they had when they were initially deployed (Table 5.3-1). In the case of ST013, a quarterly deposition rate of zero was used in Quarter 3 data presentations.

Figures 5.3-18a-b display the grain size distributions for all sediment trap samples analyzed. Samples from each station generally showed similar grain size distributions, except for an increase in the coarse-grained fraction (i.e., sand) during the winter quarter (Quarter 1) at stations ST008, ST009, and ST010, and during the fall quarter (Quarter 4) at ST007 during the 2006/2007 sampling event. Trends cannot be established for the trap data collected during the 2009 sampling event due to the lack of information in Quarter 3. The higher rate of sediment accumulation and the entrainment of sandy material in the sediment traps placed between RM 11.5 and 15.7 during Quarter 1 of the 2006/2007 sampling event and Quarter 4 of the 2009 sampling event may be due in part to the frequency of higher flow events that occurred during this period (Figures 5.3-20a-b). The distribution of flows shows that the highest daily flows during 2006/2007 Quarter 2 and 2009 Quarter 4 were approximately the same as median 2006/2007 Quarter 1 flows. Approximately 75 percent of the 2006/2007 Quarter 1 daily discharge levels were higher than any of those recorded during 2006/2007 Quarters 3 and 4 and 2009 Quarter 3. A lower accumulation of trapped sediments, particularly at upriver stations, occurred during 2006/2007 Quarters 3 and 4 and 2009 Quarter 3 when comparatively low-flow events were typical.

5.3.4 Total PCBs in Mobile Sediment

PCB congener analysis was conducted for all 65 sediment trap samples; 60 of these samples were also analyzed for PCB Aroclors (Tables 5.3-2 through 5.3-7). PCB congeners were detected in all 52 samples, with total PCB congener concentrations ranging from 0.925 J to 11,100 J µg/kg (Figures 5.3-1a-b). PCB Aroclors were detected in 41 of the 60 samples analyzed, with total Aroclor concentrations ranging from 3.1 U to 2,600 µg/kg (Figures 5.3-2a-b).

The relationship between total PCB congener and total PCB Aroclor concentrations is shown in Figure 5.3-17 and discussed in detail in Appendix D1.4. The sediment trap correlation between paired congener and Aroclor totals is r^2=0.7. Although the PCB concentrations in sediment trap samples correlated well for the two methods, concentrations of total PCBs measured as congeners were higher overall than total PCBs measured as Aroclors. The methods used for analysis of PCB congeners and Aroclors are fundamentally different and would be expected to yield moderate differences in total PCBs concentrations, as described in Appendix D1.4. In addition, among detected Aroclor results for the sediment trap samples about one-third of the individual concentrations (19 of 60 results) were below the method reporting limit (MRL).

5.3.4.1 Total PCBs Spatial and Temporal Evaluation in Study Area

The total PCBs concentrations varied by 3 orders of magnitude throughout the site. PCB congener concentrations were the highest in sediment traps located in the vicinity of

RM 11.3E (ST007 measured in 2006/2007 and ST003 measured in 2009) compared to other locations (Figures 5.3-1a-b). The greatest sample concentration (11,100 µg/kg) was measured in the fourth quarter of 2007. PCB congener concentrations at Station ST007 during low- and medium-flow periods (Quarters 2, 3, and 4) of the 2006/2007 sampling event were elevated 2 to 3 orders of magnitude above concentrations at other locations for the respective periods. Other significant peaks are noted in 2009 at ST001 and ST002 just downstream of ST003, and in 2007 offshore of Fireboat Cove (ST015; RM 9.7W), in Swan Island Lagoon (ST006), and in Willamette Cove (ST013; RM 6.7E). PCB Aroclors show the same notable peaks at ST013, ST006, and ST007 (2006/2007 data set) and ST003 (2009 data set) as shown in Figures 5.3-2a-b.

During the 2006/2007 sampling event, increasing concentrations generally occurred with each successive period at all stations except ST002 (RM 1.8W) and ST011 (RM 3.5 E), a trend that was clear in the PCB congener data but not apparent for Aroclors (Figures 5.3-2a-b). The lack of an apparent trend with Aroclors is possibly due to higher detection limits for Aroclors resulting in a lower number of samples with detectable Aroclor concentrations. The 2009 data show the same temporal pattern, as Quarter 3 of the 2009 data set approximately corresponds in season to Quarter 4 of the 2006/2007 data set, and Quarter 4 corresponds to Quarter 1 of the 2006/2007 data set.

Figures 5.3-1a and 5.3-2a show that concentrations in sediment traps are generally greater on the eastern shore of the river than the western shore. Concentrations also are greatest in sediment traps deployed at the upper end of the Study Area and show an apparent decreasing pattern in the downstream direction. There are two major exceptions to this observation at the upper end of the Study Area. The first is the sequence of sediment traps in the eastern nearshore area from RM 11.3, 9.9, and 6.7 (ST007, ST006, and ST013) where the concentrations go from extremely high, to extremely low and then peak again before gradually decreasing through the Study Area. Conversely, the sequence of sediment traps in the western nearshore area from RM 11.5, 9.7, and 7.5 (ST008, ST015, and ST014) show the concentration go from extremely low, to extremely high, and then show a decreasing pattern through the Study Area. Both Aroclors and PCB congeners show these patterns.

The 2009 data are limited to the eastern nearshore area from RM 11.1 to 12.2. These sediment traps show that concentrations are generally the same in the upper river traps (ST007, ST006, and ST005) and then increase in trap ST004 before spiking in trap ST003 and then decreasing in ST002 and ST001. This pattern seems to show that there is a lateral and/or a bedded sediment source of elevated PCBs in the vicinity of ST004 and ST003 that is influencing the concentration of the mobile sediments in those traps and the traps immediately downstream (ST002 and ST001). Both Aroclors and PCB congeners show this pattern.

Also, the lowest concentrations from the 2006/2007 event were observed during the higher river flows (Figures 5.3-19a-b and 5.3-20a-b) in Quarters 1 and 2; however, this period had the most accumulation in the traps (Figure 5.3-21a), suggesting that localized suspended sediments with elevated PCB levels are diluted by inputs of cleaner suspended sediment deposited during river higher flows. During the summer period (Quarter 3), the river flows and sediment accumulation are the lowest, but the concentrations were the second highest. This observation suggests more influence of the localized elevated suspended sediment levels on the material being deposited in the traps during low flows. The highest concentrations occurred when the river flows transitioned from low flow and were beginning to increase due to increasing storm events (late summer into fall). The accumulation in the traps during this time period is still quite low, suggesting that this is the period when the highest relative percentage of the more contaminated sediment is being mobilized.

5.3.4.2 Total PCBs Relationship by River Reach

Total PCB congener concentrations in the Study Area samples were all higher than the average PCB concentrations from upstream locations (ST009 and ST010)—1-to-5 fold greater than upstream concentrations, in most cases. These trends were generally also reflected in the Aroclor data. The downstream total PCBs concentrations (ST001 and ST002) are generally the same as the concentrations observed in Multnomah Channel (ST003) and seem to be approaching upriver concentrations, although the total PCB congener concentrations are about 2-fold higher. The concentrations entering the site, at least in the eastern nearshore region (ST005, ST006, and ST007 of the 2009 data set) are similar in concentration to the upriver sediment traps (ST009 and ST010) indicating that for the time periods measured, the downtown reach has little to no influence on the incoming depositional sediment concentrations.

5.3.5 Total PCDD/Fs and TCDD TEQ in Mobile Sediment

Total PCDD/Fs and TCDD TEQ analysis was conducted for 60 sediment trap samples (Tables 5.3-2 through 5.3-7). Total PCDD/Fs were detected in all 60 samples, with concentrations ranging from 5.16 J to 6,100 pg/g. TCDD TEQs were also detected in all 60 samples analyzed, with concentrations ranging from 0.0529 J to 16.3 J pg/g.

5.3.5.1 Total PCDD/Fs Spatial and Temporal Evaluation in Study Area

The highest total PCDD/Fs concentration (6,100 J pg/g) occurred during Quarter 4 of the 2006/2007 sampling event at ST006 (Swan Island Lagoon) (Figures 5.3-3a-b). This sample was elevated 1 to 2 orders of magnitude above concentrations at most other locations. However, a temporal evaluation of PCDD/Fs at ST006 could not be conducted as no samples from previous quarters were analyzed for total PCDD/Fs at this location. Additional total PCDD/Fs peaks of 1,820 J and 1,250 J pg/g occurred during Quarter 3 of the 2006/2007 sampling event at ST007 (RM 11.3E) and at ST002 (RM 1.8W), respectively. Relatively high concentrations were also seen in Quarter 4 samples of the 2006/2007 sampling event in traps ST014 (RM 7.5W; 1,060 J pg/g) and ST007 (745 J pg/g), and Quarter 1 samples of the 2006/2007 sampling event in traps ST001 (RM 1.9E; 563 pg/g) and ST011 (RM 3.5E; 535 pg/g).

Total PCDD/Fs concentrations were greatest in Quarter 3 of the 2009 data set, with the highest concentration (1,640 pg/g) in sediment trap ST001 at RM 11E followed by traps ST004 (RM 11.5E; 1,280 pg/g), ST003 (RM 11.3E; 1,120 pg/g), and ST006 (RM 11.8E; 900 pg/g). Relatively high concentrations were also seen in Quarter 4 of the 2009 sampling event in trap ST005 (RM 11.8E; 879 J pg/g). The lower flow period (Quarter 3) concentrations in the 2009 data set are consistently greater than the higher flow period (Quarter 4) concentrations, suggesting that the concentration at ST005 during Quarter 3 may have had the greatest sample concentration in this area.

Samples collected in the 2006/2007 sampling event with total PCDD/Fs concentrations greater than 500 pg/g are observed in ST001 (RM 1.9E) and ST011 (RM 3.5E) during Quarter 1; ST002 (RM 1.8W) and ST007 (RM 11.3E) during Quarter 3; and ST014 (RM 7.5W), ST006 (Swan Island Lagoon), and ST007 (RM 11.3E) during Quarter 4.

There is no consistent spatial gradient or trend in total PCDD/Fs concentrations throughout the river, indicating that concentrations measured in sediment traps are more representative of localized sediments. The highest total PCDD/Fs concentrations among stations generally occurred during Quarters 4 and 3. Stations ST007 and ST009 in the eastern nearshore zone at RM 11 and 15 contained higher total PCDD/Fs than ST008 and ST010 placed at similar river miles in the western nearshore zone throughout the 2006/2007 sampling period. These results indicate that solids collected in the traps in this portion of the river in part reflect localized inputs specific to the eastern or western nearshore zones rather than being representative of river-wide mobile sediments.

5.3.5.2 TCDD TEQ Spatial and Temporal Evaluation in Study Area

The highest TCDD TEQ was found in the Quarter 4 sample of the 2006/2007 sampling event in trap ST006 (Swan Island Lagoon) (Figures 5.3-4a-b). As with total PCDD/Fs, Quarter 4 was the only time TCDD TEQs were analyzed at this location so it is difficult to gauge the occurrence of similar TCDD TEQ concentrations during other periods. TCDD TEQs greater than 1 pg/g were measured during the 2006/2007 sampling event at ST001 (RM 1.9E), ST011 (RM 3.5E), and ST005 (RM 6.0W) during Quarter 1; ST002 (RM 6.0W) during Quarter 2; ST002 (RM 1.8W) and ST007 (RM 11.3E) during Quarter 3; and ST014 (RM 7.5W), ST006 (Swan Island Lagoon), ST007 (RM 11.3E) during Quarter 4. During Quarter 3 of the 2009 sampling event, TCDD TEQ values greater than 1 pg/g occurred in all sediment traps except ST002 and were not analyzed in ST005. TCDD TEQ values greater than 1 pg/g were also present in Quarter 4 of the 2009 sampling event in traps ST004 and ST0005. TCDD TEQ spatial and temporal patterns were similar to total PCDD/Fs patterns.

5.3.5.3 Total PCDD/Fs and TCDD TEQ Relationship by River Reach

Study Area locations generally had total PCDD/Fs and TCDD TEQ concentrations higher than concentrations from the upstream locations. However, total PCDD/Fs and TCDD TEQ concentrations from the two upstream locations were not similar to each other, with concentrations from ST009 (RM 15.7E) averaging more than 6 times those from ST010 (RM 15.6W). Some ST009 samples had comparatively higher total PCDD/Fs and TCDD TEQ concentrations than concurrently sampled Study Area locations during the same quarters (Figures 5.3-3a and 5.3-4a).

Total PCDD/Fs and TCDD TEQ concentrations in the downstream reach were elevated above the upriver sediment traps (ST009 and ST010) at ST001 (RM 1.9E) and ST002 (RM 1.8W). Total PCDD/Fs and TCDD TEQ in the Study Area reach were also elevated above the upriver traps at traps ST011 (RM 3.5E), ST014 (RM 7.5W), ST006 (Swan Island Lagoon), and ST007 (RM 11.3E). Total PCDD/Fs in the Study Area were also elevated above the upriver traps at ST005 (RM 6.0W).

Total PCDD/Fs concentrations downstream of the Study Area were greater in Multnomah Channel (ST003) during Quarter 4 of the 2006/2007 sampling event than in the lower Study Area (RM 3.5 to 7.5). TCDD TEQ concentrations were also elevated in this sample. Mobile sediments were also greater downstream at ST002 (RM 1.8W) during Quarter 3 of the 2006/2007 sampling event than anywhere else below RM 11.3E (ST007) in the main channel, and at ST001 (RM 1.9E) during Quarter 1 of the 2006/2007 sampling event than anywhere in the main channel of the Study Area.

5.3.6 Total DDx in Mobile Sediment

Total DDx analysis was conducted for 63 sediment trap samples (Tables 5.3-2 through 5.3-7). DDx compounds were detected in all but two sediment trap samples. Concentrations of total DDx ranged from 0.69 to 150 µg/kg in samples with detectable concentrations.

5.3.6.1 Total DDx Spatial and Temporal Evaluation in Study Area

The highest total DDx concentration (150 µg/kg) occurred during Quarter 4 of the 2006/2007 sampling event at ST007 (RM 11.3E) and was approximately 5 times higher than the next highest sample. Total DDx concentrations greater than 10 µg/kg are observed in sediment traps ST007 (RM 11.3E), ST006 (Swan Island Lagoon), ST011 (RM 3.5E), and ST014 (RM 7.5W) during Quarter 3 of the 2006/2007 sampling event. During Quarter 4 of the 2006/2007 sampling event, peak total DDx concentrations are observed in traps ST007 (RM 11.3E), ST006 (Swan Island Lagoon), ST004 (RM 6.0E), ST015 (RM 9.7W), ST014 (RM 7.5W), ST005 (RM 6.0W), and ST012 (RM 4.5W). Total DDx concentrations greater than 10 µg/kg occurred in the 2009 sampling event in trap ST001 (RM 11E) during Quarter 3 and trap ST003 (RM 11.3E) during Quarters 3 and 4.

At most locations in 2006/2007, total DDx concentrations were highest during Quarter 4 from mid-August to mid-November. In 2009, total DDx concentrations were also highest during Quarter 4, although the time frame was mid-September to mid-January for that sampling event (Figures 5.3-5a-b). However, both Quarter 4 sampling events caught the rising limb of the hydrograph (Figures 5.3-19a-b), suggesting elevated levels of total DDx on suspended sediments enter the river system during periods of increasing precipitation. The spatial patterns of sediment trap data from the Study Area indicate inputs of elevated total DDx sediment at RM 11.3E and at RM 6E, which may also be the downstream deposition of sediments from RM 11.3. Elevated levels of total DDx in suspended sediments are also observed in Swan Island Lagoon. In the western nearshore zone, elevated concentrations are evident at RM 6.0W and 7.5W. Less prominent elevated concentrations are observed at RM 9.7W and 4.5W.

Patterns of relative concentrations of DDx constituents among samples are somewhat confounded by elevated detection limits and interferences. Detection limits were elevated in 18 percent of the samples, and another 4 percent were classified as non-detects due to contamination in the associated laboratory or field blanks (Anchor and Integral 2008c). The elevated detection limits could obscure low concentrations of total DDx. In addition, 37 percent of the results were qualified as tentatively identified and estimated (NJ) during data validation due to poor confirmation, and another 49 percent were estimated (J) as a result of the confirmation data.

5.3.6.2 Total DDx Relationship by River Reach

Total DDx concentrations in Study Area samples were generally higher than those from upstream locations. Overall, 24 of the 63 (38 percent) Study Area samples had higher total DDx concentrations than the maximum concentration from upstream samples. Differences between Study Area and upstream samples were most pronounced during Quarters 3 and 4 of both the 2006/2007 and 2009 sampling events. By contrast, Study Area samples from the first two quarters had total DDx concentrations that are only nominally higher than the concentrations observed in the upstream samples.

Concentrations of total DDx in the downstream reach at ST001 (RM 1.9E) were elevated above the upriver sediment traps (ST009 and ST010); however, ST002 (RM 1.8W) concentrations seemed consistent with the upriver concentrations. Total DDx in all the Study Area reach traps were also elevated above the upriver traps except traps ST016 (RM 9.9E) and ST013 (RM 6.7E).

Total DDx concentrations in Multnomah Channel (ST003) during the 2006/2007 sampling event were lower than or about the same as in the Study Area. Mobile sediments were also lower downstream at ST002 (RM 1.8W) than at ST001 (RM 1.9E) or ST003 (Multnomah Channel).

5.3.7 Total PAHs in Mobile Sediment

Total PAHs analysis was conducted for 62 sediment trap samples (Tables 5.3-2 through 5.3-7). PAHs were detected in all samples analyzed, with concentrations of total PAHs ranging from 77 J to 11,000 µg/kg.

5.3.7.1 Total PAHs Spatial and Temporal Evaluation in Study Area

Total PAHs concentrations varied by over 2 orders of magnitude throughout the site. Concentrations were the highest in sediment traps located in the vicinity of RM 6.0W (ST005 measured in 2006/2007) compared to other locations (Figures 5.3-6a-b). The highest concentration (11,000 µg/kg) was measured in the fourth quarter of 2007. Other elevated levels (greater than or equal to 1,000 µg/kg) are noted in 2007 at ST006 (Swan Island Lagoon), ST014 (RM 7.5W), ST004 (RM 6.0E), ST011 (RM 3.5E), ST014 (RM 7.5W), ST012 (RM 4.5W), and in 2009 at ST001 and ST003 within RM 11E and 11.3E.

During the 2006/2007 sampling event, the highest total PAHs concentrations within stations tended to occur during Quarters 3 and 4, but additional seasonal differences among stations were not apparent. The lack of an apparent trend is possibly due to the lack of samples collected for every quarter at all stations. The 2009 data set also shows the lack of a trend where some samples are greater in Quarter 3 while others are greater in Quarter 4.

Figure 5.3-6a shows that concentrations in sediment traps are generally greater on the western shore of the river than the eastern shore. Concentrations also are greatest in sediment traps deployed at the middle of the Study Area and are generally higher downstream of this area compared with upstream.

The 2009 data are limited to the eastern nearshore area from RM 11.1 to 12.2. These sediment traps show that concentrations vary throughout the area. This pattern seems to show that there may be localized sediment contamination that is influencing the concentration of the mobile sediments in this area.

Also, the lowest concentrations were observed during the higher river flows (Figures 5.3-19a-b and 5.3-20a-b) in Quarters 1 and 2 of the 2006/2007 sampling event; however, this period had the most accumulation in the traps (Figure 5.3-21a), suggesting that localized inputs are diluted by the larger volume of cleaner material being transported and deposited during higher river flows. During the summer period (Quarter 3), the river flows and sediment accumulation are the lowest, but the concentrations were the second highest. This pattern suggests that there is more localized influence on the material being deposited during low flow periods. The highest concentrations occurred when the river flows transitioned from low flow and were beginning to increase due to increasing storm events (late summer into fall). However, the accumulation in the traps during this time period is still quite low, suggesting that this is the period when more contaminated sediments are being mobilized in (resuspended bed material) and adjacent (e.g., stormwater discharge) to the site.

5.3.7.2 Total PAHs Relationship by River Reach

Total PAHs concentrations were greater upriver in ST010 (RM 15.6W) during Quarter 1 of the 2006/2007 sampling event than all other samples, except ST005 (RM 6.0W). Overall, 32 of the 34 (94 percent) Study Area samples had total PAHs concentrations higher than concurrent samples from upstream locations, with the exception of Quarter 1, where the total PAHs concentration of upstream sample ST010 (1,300 µg/kg) was higher than all but one Study Area sample (ST005). Generally, concentrations in the Study Area were within an order of magnitude of the upriver concentrations, with the exception of samples collected at ST005 (RM 6.0W) where concentrations were up to 40 times the upriver concentrations.

Samples in the upper reaches (RM 8 to 11.8) of the Study Area are consistent with samples collected upriver, although the 2009 data indicate that there are relatively high total PAHs levels in the vicinity of RM 11E. The 2009 data also show that there is variability in localized areas of the site (Figure 5.3-6b), with concentrations ranging by a factor of 5 within the river mile. The downstream total PAHs concentrations (ST001 and ST002) range from about 2 to 4 fold higher than the upriver concentrations. In general, total PAHs concentrations were higher at locations between RM 3 and 6, including Multnomah Channel (ST003), which had a relatively high Quarter 4 level (2,300 J µg/kg), than in other sampled locations (Figure 5.3-6a).

5.3.8 Bis(2-ethylhexyl)phthalate in Mobile Sediment

BEHP analysis was conducted for 61 sediment trap samples (Tables 5.3-2 through 5.3-7). BEHP was detected in all samples analyzed at concentrations ranging from 35 to 1,600 µg/kg.

5.3.8.1 BEHP Spatial and Temporal Evaluation in Study Area

BEHP concentrations varied by 2 orders of magnitude throughout the site. BEHP concentrations were greatest during Quarters 3 and 4 of the 2006/2007 sampling event (1,600 and 710 µg/kg) at ST006 (Swan Island Lagoon), although samples were not analyzed at ST006 during Quarters 1 and 2 (Figure 5.3-7a). High concentrations were also noted at ST007 (RM 11.3E) during Quarters 2, 3, and 4, and ST015 (RM 9.7W) during Quarter 4. Concentrations throughout the site were generally less than 250 µg/kg, except as noted above, and varied most during Quarter 4 of the 2006/2007 sampling event, with values ranging by a factor of 4 (excluding the high concentrations noted above). There is no observable spatial or temporal trend in the concentrations of BEHP throughout the site.

Concentrations measured in the 2009 sampling event (Tables 5.3-6 and 5.3-7; Figure 5.3-7b) reveal that concentrations in localized areas of the site vary widely. Concentrations in Quarter 3 varied by a factor of 5, while concentrations in Quarter 4 varied by a factor of 3. Relatively high concentrations (greater than 250 µg/kg) are noted in ST002, ST006, and ST007 during Quarter 3, and ST001, ST002, ST003, ST005, and ST006 during Quarter 4.

5.3.8.2 BEHP Relationship by River Reach

Upstream BEHP concentrations at ST009 (RM 15.7E) and ST010 (RM 15.6W) were generally lower than Study Area locations during concurrent sampling. During Quarter 4, however, the BEHP concentration at ST010 (480 J µg/kg) was higher than at all Study Area locations except ST006 (Figure 5.3-7a). Quarter 3 also showed a higher upriver concentration in ST009 (210 µg/kg) than at ST004 (81 µg/kg) and ST012 (150 µg/kg).

Concentrations in the downstream traps (ST001 and ST002) and in Multnomah Channel (ST003) were lower than concurrent Study Area traps. In Quarters 1 and 2, the downstream traps show that mobile concentrations were at or approaching upriver concentrations. During Quarters 3 and 4, the downstream traps had lower concentrations than the upriver traps.

5.3.9 Total Chlordanes in Mobile Sediment

One or more chlordanes were detected in 37 of the 63 samples analyzed (Tables 5.3-2 through 5.3-7). Detectable concentrations of total chlordanes ranged from 0.22 J to 3.7 NJ µg/kg. Extremely high reporting limits for non-detects are noted in trap ST007 during Quarters 3 and 4 of the 2006/2007 sampling event (98 and 460 µg/kg, respectively) and in trap ST003 during Quarter 4 of the 2009 sampling event (86 µg/kg). Detection limits were also notably high in traps ST001 and ST003 during Quarter 3 of the 2009 sampling event (3.2 and 4.3 µg/kg, respectively). These elevated non-detects appear to be due to matrix interferences. These samples all had relatively high PCB levels, which may have interfered with the pesticide quantification.

5.3.9.1 Total Chlordanes Spatial and Temporal Evaluation in Study Area

The highest detected total chlordanes concentration was found at ST008 (RM 11.5W) during Quarter 1 (Figures 5.3-8a-b). Other comparatively high detected concentrations (>3 µg/kg) were found during Quarter 4 at ST011 (RM 3.5E) and during Quarter 3 at ST006 (Swan Island Lagoon). Total chlordanes concentrations were highly variable within and among locations and within and among seasons. Higher concentrations were noted in Quarters 1, 3, and 4 of the 2006/2007 sampling event than in Quarter 2. Although west-side samples had higher levels during Quarter 1 than east-side sediment traps, variations in data were difficult to assess due to the number of non-detects and the vast range of reporting limits. Therefore, spatial and seasonal gradients or trends were not apparent.

5.3.9.2 Total Chlordanes Relationship by River Reach

Overall, Study Area total chlordanes concentrations were higher than upstream concentrations. The maximum total chlordanes concentration in upstream samples was 1 NJ µg/kg, whereas 9 of the 14 Study Area stations had at least 1 sample with greater than 1 µg/kg total chlordanes. Only one downstream sample in ST002 had a concentration greater than 1 µg/kg.

5.3.10 Aldrin and Dieldrin in Mobile Sediment

Aldrin and dieldrin, two closely related organochlorine pesticides, were analyzed in 63 samples. Aldrin was detected in seven samples and dieldrin was detected in six samples (Tables 5.3-2 through 5.3-7). Only one of the samples analyzed contained detectable levels of both aldrin and dieldrin for the same sample (the 2009 Quarter 4 sample at ST004, RM 11.5E). Extremely high reporting limits for non-detects are noted for the 2006/2007 sampling event in trap ST008 during Quarter 1 for both aldrin and dieldrin (1.6 and 3 µg/kg, respectively), traps ST004 and ST007 during Quarter 3 for dieldrin

(1.1 and 13 µg/kg), and in trap ST006 during Quarter 4 for aldrin (1.2 µg/kg). All other non-detected values were less than 1 µg/kg.

The detected concentrations of aldrin ranged from 0.11 J to 1.1 NJ µg/kg (Figures 5.3-9a-b), with the highest concentration found at Station ST005 (RM 6W). Two of the detected aldrin samples were at downstream locations ST001 (RM 1.9E) and ST003 (Multnomah Channel). Detected dieldrin concentrations were more variable (Figures 5.3-10a-b), with concentrations ranging from 0.15 NJ µg/kg to a maximum of 4.9 µg/kg at ST006 (Swan Island Lagoon). Two of the six dieldrin detections were at the upstream location ST009 (RM 15.7E) and one was downstream at ST003 (in Multnomah Channel).

5.3.10.1 Aldrin and Dieldrin Spatial and Temporal Evaluation in Study Area

There were five detected values for aldrin within the Study Area. Two aldrin detections occurred during Quarter 1 of the 2006/2007 sampling event at ST005 (RM 6.0W) and ST012 (RM 4.5W), one detection occurred during Quarter 4 of the 2006/2007 sampling event at ST014 (RM 7.5W), and two detections occurred during Quarter 4 of the 2009 sampling event at ST002 (RM 11.1E) and ST004 (RM 11.5E).

There were three detectable dieldrin concentrations within the Study Area. Two were measured during Quarter 3 of the 2006/2007 sampling event at ST006 (Swan Island Lagoon) and ST011 (RM 3.5E), and one was measured in Quarter 4 of 2009 at ST004 (RM 11.5E).

The infrequency of detections did not allow for assessment of a possible geographical concentration gradient or trend. However, detected aldrin concentrations occurred primarily at or below RM 7.5 in the western nearshore zone, while dieldrin was detected primarily in the eastern nearshore zone.

5.3.10.2 Aldrin and Dieldrin Relationship by River Reach

Aldrin was not detected in upriver samples, but was detected in two downstream samples, ST001 (RM 1.9E) and ST003 (Multnomah Channel) during Quarter 1 of the 2006/2007 sampling event. Dieldrin was detected upriver at ST009 (RM 15.7E) during both Quarters 3 and 4 of the 2006/2007 sampling event, but was only detected downstream at ST003 (Multnomah Channel) during Quarter 4. There were not enough data to determine any relationship for aldrin and dieldrin between river reaches.

5.3.11 Arsenic in Mobile Sediment

Arsenic was detected in all 62 samples analyzed at concentrations ranging from 1.48 J to 7.01 mg/kg (Tables 5.3-2 through 5.3-7).

5.3.11.1 Arsenic Spatial and Temporal Evaluation in Study Area

There was relatively little variation in concentrations among samples within the Study Area, with values ranging between 2.75 and 7.01 mg/kg (Figures 5.3-11a-b). The highest arsenic concentration was found at Station ST011 (RM 3.5E) during Quarter 4 of the 2006/2007 sampling event. The highest levels were generally found during Quarter 4, particularly downstream of RM 9, although Quarter 2 showed equally high levels in the upper Study Area (RM 9.7–11.5).

5.3.11.2 Arsenic Relationship by River Reach

Most concentrations of arsenic from Study Area stations were similar to or slightly above arsenic concentrations in upriver locations. Arsenic levels in Study Area samples rarely varied from the arsenic levels at upstream stations by more than a factor of 2. Downstream samples had similar concentrations to those in the Study Area, and were also generally greater than the upriver samples by a factor of 2.

5.3.12 Chromium in Mobile Sediment

Chromium was detected in all 62 samples analyzed at concentrations ranging from 10.8 J to 59.5 mg/kg (Tables 5.3-2 through 5.3-7).

5.3.12.1 Chromium Spatial and Temporal Evaluation in Study Area

There was relatively little variation in concentrations among samples within the Study Area, with values ranging between 16.8 and 47.1 mg/kg (Figures 5.3-12a-b). The highest chromium concentration in the Study Area was found during Quarter 1 of the 2006/2007 sampling event at Station ST013 (RM 6.7E). The highest concentrations within stations also tended to occur during Quarter 1. The only other sample collected within the Study Area greater than 40 mg/kg was at ST006 (Swan Island Lagoon) during Quarter 3 of the 2006/2007 sampling event. The majority of the 2009 data set had concentrations less than 30 mg/kg. There were no locations with levels of chromium consistently higher than all others, and there was little variability between samples collected on either shore of the river.

5.3.12.2 Chromium Relationship by River Reach

Although the highest chromium concentration was found in ST009 (RM 15.7E) in the upriver reach during Quarter 3 of the 2006/2007 sampling event, the majority of samples in this reach range between 30 and 40 mg/kg. Likewise, most chromium concentrations from Study Area stations were within the range of samples typically found in the upriver reach. Downstream samples ranged from 16.8 J to 40.4 mg/kg with the majority of values also typically within the 30–40 mg/kg range.

5.3.13 Copper in Mobile Sediment

Copper was detected in all 62 samples analyzed at concentrations ranging from 15.2 to 93.6 mg/kg (Tables 5.3-2 through 5.3-7). There was relatively little variation in concentrations among samples, with the majority of the values within a factor of 3.

5.3.13.1 Copper Spatial and Temporal Evaluation in Study Area

The highest copper concentration was found at Station ST006 (Swan Island Lagoon) during Quarter 3 of the 2006/2007 sampling event (Figures 5.3-13a-b). The highest concentrations among sampling periods per station often occurred during Quarter 4 of the 2006/2007 sampling event, particularly at stations from RM 3.5 through 6.7. The majority of samples collected in Quarter 4 were greater than 50 mg/kg, while the majority of samples collected in other quarters were generally between 30 and 50 mg/kg. All samples collected during the 2009 sampling event were less than 43 mg/kg. Samples greater than 50 mg/kg are noted from the 2006/2007 sampling event during Quarter 1 at ST013 (RM 6.7E), during Quarter 2 at ST004 (RM 6.0E) and ST013 (RM 6.7E), during Quarter 3 at ST006 (Swan Island Lagoon) and ST011 (RM 3.5E), and during Quarter 4 at ST004 (RM 6.0E), ST005 (RM 6.0W), ST006 (Swan Island Lagoon), ST007 (RM 11.3E), ST011 (RM 3.5E), ST012 (RM 4.5W), and ST013 (RM 6.7E).

5.3.13.2 Copper Relationship by River Reach

Although the second highest copper concentration was found in a sample from one of the upstream locations (ST009) during Quarter 3 of the 2006/2007 sampling event, the majority of samples in this reach are less than 43 mg/kg. Most copper concentrations from Study Area stations were slightly above upriver copper concentrations collected during the same time period, except during Quarter 3, as mentioned above. Copper levels in Study Area samples rarely varied from the copper levels at upstream stations by more than a factor of 2. Downstream samples ranged from 25.1 to 52.4 mg/kg, which is similar to the majority of samples measured in the Study Area.

5.3.14 Zinc in Mobile Sediment

Zinc was detected in all 62 samples analyzed at concentrations ranging from 71.5 to 319 mg/kg (Tables 5.3-2 through 5.3-7). There was relatively little variation in concentrations among samples, with concentrations being within a factor of 3.

5.3.14.1 Zinc Spatial and Temporal Evaluation in Study Area

The highest zinc concentration was found during Quarter 3 of the 2006/2007 sampling event at Station ST006 (Swan Island Lagoon). ST006 was the only station that appeared to contain comparatively high localized concentrations, although only data from two quarters were available from this location. Among sampling periods (Figures 5.3-14a-b), the highest zinc concentrations per station most often occurred during Quarter 4 of the 2006/2007 sampling event. Quarter 4 of the 2009 sampling event generally had the lowest zinc levels among sampling periods. The majority of samples collected were less than 140 mg/kg. Samples greater than 140 mg/kg are noted from the 2006/2007 sampling event during Quarter 2 at ST015 (RM 9.7W), during Quarter 3 at ST006 (Swan Island Lagoon) and ST011 (RM 3.5E), and during Quarter 4 at ST004 (RM 6.0E), ST005 (RM 6.0W), ST006 (Swan Island Lagoon), ST007 (RM 11.3E), ST011 (RM 3.5E), ST012 (RM 4.5W), ST013 (RM 6.7E), ST015 (RM 9.7W) and ST016 (RM 9.9E).

5.3.14.2 Zinc Relationship by River Reach

Most concentrations of zinc from Study Area stations were slightly above zinc concentrations in upriver locations, except during Quarter 3 of the 2006/2007 sampling event. Zinc levels in Study Area samples rarely varied from the zinc levels at upstream stations by more than a factor of 2 during the same sampling period. Downstream samples ranged from 101 to 160 mg/kg, with higher concentrations in downstream stations ST001 and ST002 during Quarter 4 of the 2006/2007 sampling event. Samples collected downstream during Quarters 1, 2, and 3 and those collected in Multnomah Channel are similar to the majority of samples measured in the Study Area, but slightly higher than upriver samples.

5.3.15 Tributyltin Ion in Mobile Sediment

TBT analysis was conducted for 60 sediment trap samples (Tables 5.3-2 through 5.3-7). TBT was detected in 46 of the samples analyzed with detectable concentrations of TBT ranging from 0.48 J to 81 μg/kg.

5.3.15.1 TBT Spatial and Temporal Evaluation in Study Area

TBT concentrations at ST006 (Swan Island Lagoon) during Quarters 3 and 4 of the 2006/2007 sampling event, the only two quarters that data were available for that station, and at ST001 during Quarter 3 of the 2009 event were elevated an order of magnitude above other locations (Figures 5.3-15a-b). Concentrations within locations were generally highest during Quarter 4, and concentrations during all sampling periods were generally highest downstream of Swan Island Lagoon. The majority of samples collected were less than 5 mg/kg. Samples greater than 5 mg/kg are noted from the 2006/2007 sampling event during Quarter 3 at ST004 (RM 6.0E), ST006 (Swan Island Lagoon), and ST014 (RM 7.5W, and during Quarter 4 at ST005 (RM 6.0W), ST006 (Swan Island Lagoon), ST007 (RM 11.3E), ST011 (RM 3.5E), and ST014 (RM 7.5W). The only sample greater than 5 mg/kg during the 2009 sampling event was during Quarter 3 at ST001 (RM 11E).

5.3.15.2 TBT Relationship by River Reach

There was only one sample out of six in the upriver reach that was detected; the detected concentration was 1.9 mg/kg. All non-detect values in the upriver reach were below this value. In general, TBT levels in the Study Area were higher than TBT level detected in the upriver reach. However, since only one of six samples from the upriver stations had a detectable TBT concentration, the degree of elevation over upstream concentrations cannot be meaningfully quantified. Concentrations of TBT in the downstream reach were generally less than 4.3 mg/kg, with only one sample greater than 5 mg/kg noted during Quarter 3 at ST002 (RM 1.8W). Downstream TBT samples are notably less than the Study Area, but greater than the upriver reach.

5.4 INDICATOR CONTAMINANTS IN SURFACE WATER

This section summarizes the surface water data collected during the RI investigation. These data include those collected between November 2004 and March 2007. The surface water study was designed to characterize surface water contaminant concentrations and flow conditions of the river during three different flow regimes: low river flow (low flow; <50,000 cfs), high river flow (high flow; >50,000 cfs), and stormwater-influenced flow (low-flow conditions with active runoff in the Study Area). The threshold discharge rate of 50,000 cfs was selected because it is the river discharge at which significant transport of streambed sediment begins (Willamette Basin Task Force 1969). The geographic locations of all surface water sampling locations are presented on Map 2.1-18.

The discussion of indicator contaminants addressed in this section focuses primarily on the following elements:

- A description of the data set for each contaminant
- The relationship of contaminant concentration with respect to flow rate
- The sampling locations and event types with elevated contaminant concentrations compared to ambient water quality criteria (AWQC)
- Locations with the highest contaminant concentrations.

The following subsections present tables and other graphical formats to support discussion and evaluation of the in-river distribution of the 14 indicator contaminants discussed in the RI main report. Additional tabular and graphical summaries of 21 contaminants in surface water are included in Appendix D3.

The final subsection in this discussion presents a site-specific evaluation of hydrophobic contaminants using four contaminants: total PCBs, dioxin/furans, total PAHs, and total DDx. This discussion presents the relationship of contaminant concentration with respect to dissolved and particulate fractions and relationship with suspended solids and associated organic carbon.

The surface water chemistry distributions and supporting information are depicted in several graphical formats: hydrographs and hyetographs of sampling events, discharge rates, and precipitation events; histograms of sample concentrations for all sampling events for the indicator contaminants; and line plots, stacked bar charts, and scatter plots for the indicator contaminants.

Hydrographs and Hyetographs: The hydrographs show the measured discharge rates during each surface water sampling event, and the hyetographs show precipitation events and amounts to provide perspective on the timing of the sampling events and the specific conditions prior to, during, and after each event. These are provided as Figures 5.4-1 through 5.4-4.

Histograms: Two types of histograms are presented for each contaminant. The first histogram provides a graphical summary of contaminant concentrations by river mile for each flow event type (high flow, low flow, and stormwater-influenced flow). These histograms present XAD dissolved (blue bars), XAD particulate (red bars), and peristaltic total (green bars) concentrations averaged for each river mile. For each analyte, data are sorted by flow event type and by location in the river channel (west and east channel and transect locations). The number above each column indicates the number of samples averaged for each river mile. Concentrations below detection limits were included in averages at the full detection limit. The second type of histogram presents particulate and dissolved concentrations measured at each surface water station as stacked bars, with particulate concentrations shown in blue and dissolved concentrations shown in red. Total concentrations are presented as purple bars. Concentrations below detection limits are shows as hollow bars at the full detection limit. For some analytes, a pair of histograms is presented to show the full y-axis concentration scale, as well as a zoom on the y-axis to show lower concentrations.

Line Plots: The line plots present the concentrations of the indicator contaminants for each flow type (high flow, low flow, stormwater-influenced) at the transect stations for all surface water sampling events. The squares, diamonds, and triangles represent the data points. Prior to generating the plots, data were averaged so that only one value per transect per sampling event is shown. NB/NS total (dissolved plus particulate) concentrations were averaged for samples from stations W027 (Multnomah Channel), W005 (RM 4), W011 (RM 6.3), and W024 (RM 16), and east, west, and mid-channel total concentrations were averaged for stations W025 (RM 2) and W023 (RM 11), where applicable. The data for the 2007 high-flow event is displayed in two colors because this event was completed in two phases with a stand-down period between high-flow conditions.

Scatter Plots: Scatter-plot presentations of the detected surface water data show concentrations of the indicator contaminants by river mile. The symbols on the scatter plots distinguish between flow types (high flow, low flow, stormwater-influenced flow) and single-point and transect samples. The evaluation of hydrophobic indicator contaminants presents indicator contaminants relationships with flow, TSS, and organic carbon. Particulate versus dissolved concentrations are also presented for detailed evaluation of the results. The symbols on the scatter plots distinguish between flow types (high flow, low flow, stormwater-influenced flow) and point and transect samples.

5.4.1 Surface Water Data Set

The Round 2A and 3A surface water sampling programs consisted of seven field collection events that occurred between November 2004 and March 2007. The seven events are listed below:

- November 2004 (Round 2A, low flow)
- March 2005 (Round 2A, low flow)

- July 2005 (Round 2A, low flow)
- January 2006 (Round 3A, high flow)
- September 2006 (Round 3A, low flow)
- November 2006 (Round 3A, stormwater-influenced flow)
- January–March 2007 (Round 3A, high flow[6]).

Other studies included in this evaluation are as follows:

- Siltronic—May and June 2005 (MFA 2005b, low flow)
- NW Natural—October 2007(Anchor 2008d, low flow)
- City of Portland—February 5, 1992 (low flow) and March 15, 2006 (low flow) (Sanders 2006, TSS only).

Peristaltic and XAD (column and filter) samples were collected during all sampling events, but not at all sampling locations. Table 5.4-1 summarizes the sampling methods at each sampling station for each sampling event.

Surface water samples were collected at 23 target locations from RM 2 to 11 in the lower Willamette River during three Round 2A sampling events in 2004 and 2005. A peristaltic pump was used to collect samples at all single-point locations. Additional samples were collected by employing a peristaltic pump and the high-volume XAD sampling method at 7 of the 23 locations, including 3 cross-sectional river transects and 4 single-point locations. During the Round 3A sampling events, surface water was collected at 18 target locations from RM 2 to 16 in 2006 and 2007. A transect station located at the upper end of Multnomah Channel (RM 2.9) was added to the program to provide a better understanding of the flux of chemicals exiting the Study Area via Multnomah Channel; and a transect station at RM 16 was added to assist with the analysis of upstream sources and loading into the Study Area. Peristaltic and high-volume samples were collected from 18 stations, including 6 transects and 12 single-point locations. Table 5.4-1 summarizes sampling methods at each station for all Round 2A and 3A sampling events. Peristaltic surface water samples were analyzed for conventional analytes, metals, and organic compounds (PCB Aroclors, organochlorine pesticides, and SVOCs). High-volume samples were analyzed by high-resolution gas chromatography/high-resolution mass spectrometry (HRGC/HRMS) for PCB congeners, PCDD/Fs, organochlorine pesticides, phthalate esters, and PAHs.

For comparison of peristaltic and XAD data on the same basis, a summed XAD concentration was calculated from the XAD column and XAD filter concentrations. In

[6] The January 2007 high-flow event was cancelled after two days of sampling due to unexpected change in flow conditions. Sampling recommenced on February 21, 2007 once high-flow conditions (>50,000 cfs) were once again observed and continued through March 10, 2007.

this sum, non-detects were set to zero. If both XAD fractions were non-detect, the summed detection limit was set to the sum of the individual detection limits.

A total of six transect locations located at RM 2, mouth of Multnomah Channel, RM 3.9, 6.3, 11, and 16 were sampled; due to flow conditions and sample event objectives, not all transects were sampled during all sampling events. Transects were sampled in three ways: as a vertically integrated equal discharge increment transect [T-EDI-VI]; as a near-surface equal discharge increment transect and near-bottom equal discharge increment transect pair [T-EDI-NS/NB]; and as a vertically integrated, three segment (east, mid-channel, west) transect [T-VI (E, M, W)][7]. At three locations (W010, W014, and W020) single point vertically integrated (SP-VI) samples were collected during Round 2A low-flow conditions to support the BHHRA. The remaining Round 2A single-point samples were collected in support of the BERA as near-bottom samples. Round 3A single-point samples were collected as near-surface and near-bottom pairs. Siltronic collected peristaltic single point samples, and NW Natural and the City of Portland collected surface water grab samples. Not all samples were analyzed for every analyte. Each subsection that follows discusses which samples were analyzed for each indicator contaminants.

A total of 16 peristaltic sample locations and 7 peristaltic and XAD stations were sampled during the Round 2A low-flow conditions, and 6 peristaltic and XAD stations were sampled during the Round 3A low-flow conditions (Table 5.4-2). Sixteen single-point peristaltic stations (W001–W004, W006–W010, W012, W014, W017, and W019–W022) and four single-point peristaltic and XAD stations were sampled (W013, W015, W016, W018) during each of the three Round 2A sampling events (Table 5.4-1). Both peristaltic and XAD samples were collected for all the low-flow transect samples in Round 2A. Three Round 2A transect locations (W005, W011, and W023) were collected during low-flow conditions as T-EDI-VI. Four Round 3A transect locations (W005, W011, W024, and W027) were collected as T-EDI-NS/NB and the other two Round 3A transect locations (W023 and W025) were collected as T-VI (E, M, W). Replicates were collected based on a 5 percent target frequency at the following single-point stations: W013 (peristaltic and XAD) and W016 (peristaltic only) during November 2004; W013 (peristaltic and XAD), W002 (peristaltic only), W004 (peristaltic only), and W016 (peristaltic only) during March 2005; and W002 (peristaltic only), W016 (peristaltic only), and W013 (peristaltic and XAD) during July 2005. A total of 92 peristaltic samples and 38 XAD samples were collected to represent the low-flow conditions of the river (Table 5.4-3). As summarized in Table 5.4-4, samples collected during this flow regime include the following:

- 61 peristaltic and 15 XAD single-point, near-bottom (SP-NB) samples
- 8 peristaltic SP-VI samples
- 9 peristaltic and 9 XAD transect, T-EDI-VI samples

[7] A single vertically integrated sample was collected from the mid-point of each transect segment.

- 2 peristaltic and 2 XAD east-channel vertically integrated transect samples, 2 peristaltic and 2 XAD mid-channel vertically integrated transect samples, and 2 peristaltic and 2 XAD west-channel vertically integrated transect samples
- 4 peristaltic and 4 XAD transect, T-EDI-NS samples
- 4 peristaltic and 4 XAD transect, T-EDI-NB samples.

Stormwater-influenced flow conditions were only sampled once during Round 3A (November 2006). Both peristaltic and XAD samples were collected at all six transect locations (W005, W011, W023, W024, W025, and W027) and 12 single-point stations (W026 and W028–W038) during this sampling event (Table 5.4-1). Four of the transect locations (W005, W011, W024, and W027) were sampled as T-EDI-NS/NB. The other two transect locations (W023 and W025) were sampled as T-VI (E, M, W). All the single-point samples were collected as SP-NS/NB pairs. Replicates were collected at single-point stations W033 (peristaltic and XAD) and W036 (peristaltic only). A total of 42 peristaltic samples and 40 XAD samples were collected to represent the stormwater-influenced flow conditions of the river (Table 5.4-3). As summarized in Table 5.4-4, samples collected during this flow regime include the following:

- 14 peristaltic and 13 XAD single-point, near-surface (SP-NS) samples
- 14 peristaltic and 13 XAD SP-NB samples
- 2 peristaltic and 2 XAD east-channel vertically integrated transect samples, 2 peristaltic and 2 XAD mid-channel vertically integrated transect samples, and 2 peristaltic and 2 XAD west-channel vertically integrated transect samples
- 4 peristaltic and 4 XAD transect, T-EDI-NS samples
- 4 peristaltic and 4 XAD transect, T-EDI-NB samples.

High-flow conditions were sampled twice during Round 3A (January 2006 and January-March 2007). In January 2006, peristaltic and XAD samples were collected at three transects (W005, W023, and W024). Due to safety concerns and sampling challenges associated with the extreme high-flow conditions, the January 2006 samples were collected mid-channel at a single fixed depth for each of the three transect stations that were sampled. No vertical integration was performed. One replicate was collected at W023 for the peristaltic sample only. Both peristaltic and XAD samples were collected at all 6 transects and 12 single-point stations (W026 and W028–W038) during the January–March 2007 sampling event. Four of the transect locations (W005, W011, W024, and W027) were sampled as T-EDI-NS/NB. The other two transect locations (W023 and W025) were sampled as T-VI (E, M, W). Stations W023-M and W025-M were first sampled in January 2007, and then reoccupied in March 2007 (W023-M2, W025-M2) due to changing flow conditions. All the single-point samples were collected as SP-NS/NB pairs. SP-NS/NB replicates were collected at single-point station W033 (peristaltic only) during the January–March 2007 event. A total of 46 peristaltic samples and 43 XAD samples were collected to represent the high-flow conditions of the river (Table 5.4-3). As summarized in Table 5.4-4, samples collected during this flow regime include the following:

- 13 peristaltic and 12 XAD SP-NS samples
- 13 peristaltic and 12 XAD SP-NB samples
- 2 peristaltic and 2 XAD east-channel vertically integrated transect samples, 4 peristaltic and 2 XAD mid-channel vertically integrated transect samples, and 2 peristaltic and 2 XAD west-channel vertically integrated transect samples
- 4 peristaltic and 4 XAD transect, T-EDI-NS samples
- 4 peristaltic and 4 XAD transect, T-EDI-NB samples.

Uncertainty associated with the surface water data is related primarily to the representativeness of the analytical data set. The surface water sampling program was designed to capture representative flow conditions and locations over time. However, only a limited number of surface water samples during a limited number of conditions could be collected over time. In addition, sampling protocols evolved over time based on the assessment of previous efforts as well changing river flow conditions. This evolution included some changes in both sample locations and sampling methods. While these changes were intended to more fully characterize the site, they also make the compilation and combination of these data more complex. For example, single-point stations occupied in Round 2 were sampled on multiple occasions. However, during Round 3, the stations were shifted into deeper water to accommodate the Round 3 modification to collect both near-bottom and near-surface samples simultaneously or were relocated at EPA's request. Also, while the six transects were sampled in almost all the sampling events, sampling methods were modified over the course of the sampling program. While the data evaluation compares concentrations at the river transects, there is uncertainty associated with the changes in sampling methods as well as the unavoidable flow condition differences between specific sampling events.

This complexity prohibits a quantitative statistical evaluation of temporal and flow variability in surface water. Further, the limited number of stations and samples preclude definition of the magnitude and extent of the surface water contamination in all localized areas. Such locations may need to be addressed further in remedial design. Nonetheless, the data collected and presented here met the objectives of the sampling program and are sufficient for the purposes of the site-wide RI.

5.4.2 River Conditions during Round 2A and 3A Sample Collection

A summary of the sampling events, including dates of collection, flow rates, and relative flow conditions, are presented in Table 5.4-5. Average discharge rates (recorded as cfs) for each event are based on measurements collected by the USGS at the stream flow station located upstream of the Morrison Bridge at RM 12.8 (station 14211720). Flow measurements from the USGS gauge at this station are collected every 30 minutes and were used to calculate flow rates for each of the seven sampling events. It should be noted that discharge rates below 20,000 cfs measured at this station are considered to be unreliable by the USGS. Therefore, the average discharge rates calculated for the low-flow events should be considered estimates.

The surface water sampling events and their corresponding flow rates are presented against the backdrop of the average year (1972–2008) hydrograph measured at Morrison Bridge on Figure 5.4-1. Overall, the sampling events were well distributed over the average water year, capturing the range of flow conditions, including base flow, rising limb, peak flow, and falling limb conditions. Additionally, the November 2006 sampling captured a storm-water-influenced flow event at the onset of the transition from a low-flow period to a high-flow period. Figures 5.4-2a-d present the actual annual hydrograph measured at Morrison Bridge (RM 12.8) and hyetograph during each year of sampling (2004–2007), including daily average and historical average (1978–2008) discharge rates and daily precipitation levels, as well as the sampling events collected during each year. Several rainfall events occurred during the November 2004 sampling event, and one day of measurable rainfall occurred during each of the March and July 2005 sampling events.

The seasonal cycle of water discharge in the Willamette River is also apparent on Figure 5.4-1. Annual low water levels occur during the summertime regional dry season, and flows increase during the wetter winter months (November to March). Furthermore, a distinct and persistent period of relatively high water levels occurs from late May through June when Willamette River flow into the Columbia is slowed by high-water stage/flow in the Columbia River during the spring freshet in the much larger Columbia River Basin. The flow regime can influence the concentration of contaminants in the water column.

Flow measurements were not collected at the lower end of the Study Area where the river flows either into the Columbia River or into Multnomah Channel. To better understand the flow dynamics at the lower end of the Study Area, a hydrodynamic model (discussed in Section 6) was used to estimate these flows. The model shows that the relative stages of the Columbia and Willamette rivers determine the fraction of the Willamette River flow which flows down Multnomah Channel (WEST 2006a). Figure 5.4-3 presents the average annual hydrograph, based on modeled discharge rates for 2003 through 2007, for RM 4, 2, and Multnomah Channel. The Morrison Bridge (RM 12.8) 25-yr average hydrograph is also shown for comparison.

Figure 5.4-4 presents the modeled daily average flows for 2003 through 2007 and highlights the time periods when surface water samples were collected at RM 4, 2, and Multnomah Channel. A few key observations are apparent in Figures 5.4-3 and 5.4-4. First, for a significant portion of each year, generally May through September, Multnomah Channel flow increases above the flow at both RM 2 and 4. During these periods, the relatively higher Columbia River stage drives a reversal in flow direction at RM 2, so that Multnomah Channel flow includes the entire Willamette River flow plus some flow from the Columbia River. Second, Figure 5.4-4 shows that surface water sampling events at the RM 2 and Multnomah Channel sample transects did not occur during these flow reversal periods; rather, sampling was conducted when the Willamette River flow was in the downstream direction, and flows split between Multnomah Channel and the main stem. This indicates that surface water samples collected at RM 2 and Multnomah Channel are representative of Willamette River water and are not strongly influenced by mixing with Columbia River water.

Tidal action also compounds the hydrology and interplay of the two rivers, and affects the Willamette River upstream as far as Portland Harbor and beyond. The high (i.e., flood) tide can influence Willamette River levels by up to 3 ft in Portland Harbor when the river is at a low stage. These tidal fluctuations can result in short-term flow reversals (i.e., upstream flow) in Portland Harbor during times of low river stage combined with large flood tides. Tidal changes were observed at multiple stations during the surface water sampling events. At this time, there is not adequate high-resolution discharge information to determine the potential influence of tidal fluctuations and water mixing on surface water sampling results; however, the overall tidal impact is not expected to be significant.

5.4.3 Suspended Solids

Suspended sediment loads are potentially an important component of the lower Willamette River physical system. TSS data have been collected as part of the surface water data collection effort to understand distributions and patterns of contaminant concentrations. As stated in Section 3, evaluations overall indicate that a positive correlation exists between TSS concentrations and flow rate in the lower Willamette River.

Organic carbon is present in both suspended sediment and the dissolved phase. This organic carbon comes from a range of natural sources including watershed inputs, such as the dissolution and decay of plant material and soil organic matter, and in-river sources such as phytoplankton. In some locations anthropogenic sources such as petroleum may be significant. Hydrophobic compounds, for example persistent organic pollutants, such as PCBs, dioxin/furans, and chlorinated pesticides, tend to accumulate in the organic fraction ($f_{oc)}$ of sediments and soils, although they can be present in aqueous solution due to the dissolved organic carbon (DOC) and the presence of colloids[8] in the water column. Organic carbon in the suspended sediment is a strong determinant in the adsorption of organic contaminants (i.e., persistent organic pollutants) with low aqueous solubilities. DOC is important in the transport of metals in the aquatic systems. Metals can be strongly complexed by DOC, enhancing metal solubility while also reducing metal bioavailability.

[8]Colloids are the smallest particles, having dimensions between 1 nm and 100 µm; they are composed of humic substances, Fe and Mn oxides and soil-derived materials, and are ubiquitous in natural waters (Stumm and Morgan 1996). A fraction of colloids is small enough to pass through 0.45-µm filter materials; as such, compounds sorbed to, or comprising, colloids are operationally part of the “dissolved” fraction.

Figures 5.4-5 and 5.4-6 present the f_{oc} on the TSS in each surface water sample as a function of flow rate and river mile, respectively. The surface water transect particulate and DOC data are presented by event on Figures 5.4-7 and 5.4-8. The f_{oc} values on the TSS range from 0 to 20 percent in the low-flow samples and 0 to 50 percent in the stormwater-influenced samples. Conversely, the f_{oc} on the TSS in high-flow samples is distinctly lower, ranging from 0 to less than 4 percent, suggesting the introduction of suspended particles with low organic carbon content during high-flow events. Generally low f_{oc} values may be a function of larger particles (lower surface area per volume and therefore fewer organic carbon binding sites) introduced during high-flow conditions.

Figure 5.4-9 presents a scatter plot of f_{oc} and TSS that summarizes the overall trend of solids concentrations and f_{oc} in the data set. High-flow samples tend to exhibit lower f_{oc} associated with TSS. The shape of the curve is largely driven by the fact that f_{oc} is a function of TSS. The suspended solids associated with the stormwater-influenced samples appear to have the highest levels of organic carbon content. The TSS concentrations and corresponding f_{oc} values vary somewhat between flow types, and the low-flow samples appear to fall between the high-flow and stormwater-influenced samples based on the level of organic carbon. There is the possibility that there may be local nearshore effects at the point of discharge that were not captured in the surface water sampling data set.

5.4.4 Total PCBs in Surface Water

Total PCB data are summarized in Tables 5.4-6 through 5.4-11. Transect samples are summarized by flow event in Tables 5.4-6, 5.4-8, and 5.4-10. Single-point samples are summarized by flow event in Tables 5.4-7a-d, 5.4-9a-d, and 5.4-11a-d. All PCB surface water sample results are presented in Table 5.4-12 by sample event and sample location.

Dissolved and particulate PCB congener concentrations in surface water XAD columns and filters and PCB Aroclor concentrations from the peristaltic pumps are presented in bar graphs by flow event and by river mile/channel position on Figures 5.4-10 and 5.4-11a-b.

Total PCB concentrations at the transect locations as a function of flow rate are presented on Figure 5.4-12. The data points presented in this figure are averages of all data points collected at a particular transect for each measured flow event.

Figures 5.4-13a-b present scatter plots of all detected total PCB congener surface water data. Note the symbols and colors indicate the sample type—point vs. transect—and the general flow conditions of the sampling event—low flow, storm-water-influenced, or high flow.

5.4.4.1 Total PCBs Data

Total PCBs were analyzed as PCB Aroclors by USEPA Method 8081 in 53 of the total 180 peristaltic samples collected: 42 SP-NB samples, 8 SP-VI samples, and 3 T-EDI-VI samples. High-volume surface water samples (XAD samples) were analyzed as PCB congeners by HRGC/HRMS in 121[9] of the total 121 XAD samples collected: 25 SP-NS samples, 40 SP-NB samples, 9 T-EDI-VI samples, 23 T-VI (E, M, W) samples, 12 T-EDI-NS samples, and 12 T-EDI-NB samples.

PCB Aroclors were not detected in the majority of the peristaltic samples (47 of 53 non-detect samples) with detection limits ranging from 0.0025 to 0.0027 µg/L, which is 3 orders of magnitude greater than the Oregon water quality criterion (WQC) for human health (6.4×10^{-6} µg/L), although below the chronic Oregon WQC for aquatic life (0.014 µg/L) and USEPA's maximum contaminant level (MCL)[10] (0.5 µg/L) for drinking water.

Detections of PCB Aroclors were limited to six single-point samples collected during the Round 2A low-flow event at the following stations:

- W001 (RM 2.0E)
- W004 (RM 3.7E–head of International Slip)
- W014 (RM 6.7E)
- W022 (RM 9.7W).

Detected PCB Aroclor concentrations for SP-NB samples range from 0.00467 J to 0.0136 J µg/L; only one SP-VI sample (W014) was detected at 0.0154 µg/L.

Total PCB congener concentrations, calculated as the sum of the dissolved (XAD column) and particulate (XAD filter) concentrations, were detected in all samples. The following discussion is based on the detected total PCB congener data.

5.4.4.2 Total PCBs Relationships to River Flow Conditions

Total PCBs concentrations in samples collected during low-flow conditions ranged as follows (sample types not sampled are also listed):

- SP-NS: Not sampled
- SP-NB: 3.75×10^{-4} J to 0.0136 J µg/L (station W013 at RM 6.9E)
- SP-VI: One sample was detected at 0.0154 µg/L (station W014 at RM 6.7E)
- T-VI (E, M, W): 2.75×10^{-4} J to 9.50×10^{-4} J µg/L (station W023-E at RM 11)

[9] Only the column of the XAD sample collected during July 2005 low-flow event was analyzed for total PCBs; the filter was not analyzed.

[10] Under Oregon State Administrative Rules, OAR 340-041-0340, Table 340A, the designated beneficial use of the lower Willamette River includes private and public domestic water supply after adequate pretreatment to meet drinking water standards. There are no known current or anticipated future uses of the lower Willamette River within Portland Harbor as a private or public domestic water supply. As such, their use in this section is solely as values for comparison.

- T-EDI-NS: 1.59×10^{-4} J to 6.73×10^{-4} J µg/L (station W011 at RM 6.3)
- T-EDI-NB: 1.74×10^{-4} J to 9.50×10^{-4} J µg/L (station W005 at RM 3.9)
- T-EDI-VI: 1.71×10^{-4} J to 6.08×10^{-4} J µg/L (station W023 at RM 11).

Total PCBs concentrations in samples collected during stormwater-influenced flow conditions ranged as follows:

- SP-NS: 1.82×10^{-4} J to 0.00259 J µg/L (station W030 at RM 5.5E)
- SP-NB: 1.12×10^{-4} J to 8.97×10^{-4} J µg/L (station W026 at RM 2.1E)
- SP-VI: Not sampled
- T-VI (E, M, W): 1.21×10^{-4} J to 0.00129 J µg/L (station W025-E at RM 2)
- T-EDI-NS: 1.49×10^{-4} J to 4.58×10^{-4} J µg/L (station W005 at RM 3.9)
- T-EDI-NB: 2.05×10^{-4} J to 4.40×10^{-4} J µg/L (station W005 at RM 3.9)
- T-EDI-VI: Not sampled.

Total PCBs concentrations in samples collected during high-flow conditions ranged as follows:

- SP-NS: 1.11×10^{-4} J to 7.49×10^{-4} J µg/L (station W035 in Swan Island Lagoon)
- SP-NB: 1.49×10^{-4} J to 7.03×10^{-4} J µg/L (station W035 in Swan Island Lagoon)
- SP-VI: Not sampled
- T-VI (E, M, W): 4.19×10^{-5} J to 2.09×10^{-4} J µg/L (station W023-M at RM 11)
- T-EDI-NS: 7.83×10^{-5} J to 2.50×10^{-4} J µg/L (station W027 in Multnomah Channel)
- T-EDI-NB: 7.05×10^{-4} J to 3.91×10^{-4} J µg/L (station W005 at RM 3.9)
- T-EDI-VI: Not sampled.

Total PCBs concentrations were consistently lower in high-flow samples compared to the low-flow and stormwater-influenced flow samples (Figure 5.4-12), suggesting dilution at high-flow rates overwhelms local effects and PCBs concentrations. All sample events show the concentrations at the RM 11 transect are consistently greater than at the RM 16 transect (Figure 5.4-12), indicating there are inputs of PCBs to the system in this reach. During three of the four low-flow sampling events (March 2005, July 2005, and September 2006), concentrations increase between RM 11 and 6. However, the November 2004 low-flow event did not show this same trend. Two of the low-flow events (July 2005 and September 2006) show sustained elevated concentrations between RM 6 and 4.

The February 2007 high-flow sampling event shows increasing concentrations between RM 6 and 4; this trend is also apparent in the November 2006 stormwater-influenced flow event. Only the stormwater-influenced event shows increasing concentrations between RM 4 and 2.Two of the three highest total PCBs concentrations at RM 11 were from the sampling stations on the east side of the channel (Figure 5.4-11a-b). The second highest result at RM 11 was from a Round 2A vertically and horizontally integrated transect, and the field crew noted stormwater runoff entering the east side of the channel during collection of this sample (Jones 2007, pers. comm.).

5.4.4.3 Spatial Distribution of Total PCBs

None of the sample results exceeds USEPA's MCL for PCBs (0.5 µg/L) for drinking water. Total PCBs results from two sample stations exceeded the chronic DEQ WQC for aquatic life (0.014 µg/L): stations W004 (RM 3.7 at the head of International Slip) and W014 (RM 6.9E in Willamette Cove). All sample results exceed the DEQ WQC for human health (6.4×10^{-6} µg/L) by 1 to 4 orders of magnitude. The majority of the highest total PCB concentrations (>0.001 µg/L) were associated with single-point samples collected during low-flow conditions.

The highest detected concentrations (>0.01 µg/L) were collected at the following stations during low-flow conditions:

- W004 (RM 3.7E at the head of International Slip)
- W013 and W014 (RM 6.9E in Willamette Cove).

The next highest detected concentrations (between 0.01 and 0.001 µg/L) were collected at the following stations during low-flow conditions:

- W001 (RM 2.0E)
- W015 (RM 6.9W)
- W016 (RM 7.2W)
- W018 (in Swan Island Lagoon)
- W022 (RM 9.7W).

Concentrations between 0.01 and 0.001 µg/L were also detected during the stormwater-influenced flow event at the following stations:

- W025-E (RM 2.0)
- W028 (RM 3.6E)
- W030 (RM 5.5E).

These data suggest that local PCB sources may exist in these regions of the Study Area. The range of total PCBs concentrations within the complete data set across the Study Area was fairly consistent between RM 11 and 2 (Figure 5.4-13a-b), excluding the highest single-point concentrations, and elevated concentrations near the east side of the river at RM 6.7. Within the Study Area, total PCBs concentrations continued to increase between RM 11 and 4 in six of seven transect-based sampling events (the sole exception is the November 2004 low-flow sampling event). Total PCBs concentrations at both RM 2 and Multnomah Channel transects generally decreased from those at RM 4 but remained higher than those at RM 16. An exception to this was the RM 2 total PCBs concentration from the November 2006 stormwater-influenced event, which was higher than other transect concentrations measured in that event.

5.4.5 Total PCDD/Fs and TCDD TEQ in Surface Water

Total PCDD/Fs and TCDD TEQ data are summarized in Tables 5.4-6 through 5.4-11. Transect samples are summarized by flow event in Tables 5.4-6, 5.4-8, and 5.4-10. Single-point samples are summarized by flow event in Tables 5.4-7a-d, 5.4-9a-d, and 5.4-11a-d. All PCDD/F and TCDD TEQ surface water sample results are presented in Tables 5.4-13 and 5.4-14, respectively, by sample event and sample location.

Dissolved and particulate PCDD/F congener concentrations in surface water XAD columns and filters and concentrations from the peristaltic pump samples are presented in bar graphs by flow event and by river mile/channel position on Figures 5.4-14 and 5.4-15. Dissolved and particulate TCDD TEQ concentrations in surface water are presented similarly on Figures 5.4-18 and 5.4-19a-b.

Total PCDD/Fs concentrations at the transect locations as a function of flow rate is presented on Figure 5.4-16. The data points presented in this figure are averages of all data points collected at a particular transect for each measured flow event.

Figure 5.4-17 presents a scatter plot of all detected total PCDD/Fs surface water data. Note the symbols and colors indicate the sample type—point vs. transect—and the general flow conditions of the sampling event—low flow, stormwater-influenced, or high flow.

5.4.5.1 Total PCDD/Fs and TCDD TEQ Data

Total PCDD/Fs were analyzed as PCDD/F congeners in high-volume surface water samples by HRGC/HRMS in 79 of the total 121 XAD samples collected, including 7 SP-NS samples, 16 SP-NB samples, 9 T-EDI-VI samples, 23 T-VI (E, M, W) samples, 12 T-EDI-NS samples, and 12 T-EDI-NB samples. Total PCDD/F congener concentrations, calculated as the sum of the dissolved (XAD column) and particulate (XAD filter) concentrations, were detected in all samples.

TCDD TEQs were calculated in 121 of the total 121 XAD samples collected, including 25 SP-NS samples, 40 SP-NB samples, 9 T-EDI-VI samples, 23 T-VI (E, M, W) samples, 12 T-EDI-NS samples, and 12 T-EDI-NB samples. Stacked bar graphs depicting TCDD TEQ concentrations in the surface water dissolved (XAD column) and particulate (XAD filter) samples by flow condition and river mile are presented on Figures 5.4-18 and 5.4-19. TCDD TEQ concentrations, calculated as the sum of the dissolved (XAD column) and particulate (XAD filter) TCDD toxicity equivalent concentrations of each dioxin/furan congener, were detected in all samples.

5.4.5.2 Total PCDD/Fs and TCDD TEQ Relationships to River Flow Conditions

Concentrations of total PCDD/Fs and TCDD TEQ during low-flow, stormwater-influenced, and high-flow conditions are summarized in this section.

5.4.5.2.1 Total PCDD/Fs Relationship to River Flow Conditions

Total PCDD/Fs concentrations in samples collected during low-flow conditions ranged as follows:

- SP-NS: Not sampled
- SP-NB: 3.07×10^{-5} to 1.62×10^{-4} μg/L (station W013 at RM 6.9E)
- SP-VI: Not sampled
- T-VI (E, M, W): 6.0×10^{-6} J to 2.7×10^{-5} J μg/L (station W023-E at RM 11)
- T-EDI-NS: 8.49×10^{-6} J to 2.58×10^{-5} J μg/L (station W027 in Multnomah Channel)
- T-EDI-NB: 9.31×10^{-6} J to 5.16×10^{-5} J μg/L (station W005 at RM 3.9)
- T-EDI-VI: 1.68×10^{-5} J to 5.05×10^{-5} J μg/L (station W005 at RM 3.9).

Total PCDD/Fs concentrations in samples collected during stormwater-influenced flow conditions ranged as follows:

- SP-NS: 3.60×10^{-5} J μg/L to 5.38×10^{-5} J μg/L (station W035 in Swan Island Lagoon)
- SP-NB: 3.90×10^{-5} μg/L to 5.52×10^{-5} J μg/L (station W032 at RM 6.9E)
- SP-VI: Not sampled
- T-VI (E, M, W): 5.51×10^{-6} J μg/L to 1.18×10^{-4} μg/L (station W023-E at RM 11)
- T-EDI-NS: 1.99×10^{-5} J μg/L to 5.22×10^{-5} μg/L (station W011 at RM 6.3)
- T-EDI-NB: 2.57×10^{-5} μg/L to 5.01×10^{-5} μg/L (station W005 at RM 3.9)
- T-EDI-VI: Not sampled.

Total PCDD/Fs concentrations in samples collected during high-flow conditions ranged as follows:

- SP-NS: 2.47×10^{-5} to 7.44×10^{-5} μg/L (station W035 in Swan Island Lagoon)
- SP-NB: 2.67×10^{-5} J to 7.49×10^{-5} μg/L (station W035 in Swan Island Lagoon)
- SP-VI: Not sampled
- T-VI (E, M, W): 5.36×10^{-6} J to 4.40×10^{-5} J μg/L (station W005 at RM 3.9)

- T-EDI-NS: $9.73{\times}10^{-6}$ J to $3.00{\times}10^{-5}$ J µg/L (station W027 in Multnomah Channel)
- T-EDI-NB: $8.14{\times}10^{-6}$ J µg/L to $2.89{\times}10^{-5}$ µg/L (station W027 in Multnomah Channel)
- T-EDI-VI: Not sampled.

Figure 5.4-16 shows that there does not appear to be an overall trend between total PCDD/Fs values and flow conditions. All sample events show concentrations at the RM 11 transect are consistently greater than concentrations at the RM 16 transect (Figure 5.4-16), indicating there are inputs of total PCDD/Fs to the system in this reach. During three of the four low-flow sampling events (March 2005, July 2005, and September 2006), concentrations of PCDD/Fs increase between RM 11 and 6.3. The July 2005 low-flow event shows increasing concentrations between RM 6.3 and 3.9. The stormwater-influenced flow event shows concentration peaks at RM 11 and 2; the February 2007 high-flow event shows a similar pattern. Concentrations of total PCDD/Fs leaving the Study Area in Multnomah Channel were consistently higher than at RM 16 upstream of the Study Area, while concentrations at RM 2 were consistently lower than RM 16 and Multnomah Channel.

5.4.5.2.2 TCDD TEQ Relationship to River Flow Conditions

TCDD TEQ concentrations in samples collected during low-flow conditions ranged as follows:

- SP-NS: Not sampled
- SP-NB: $1.10{\times}10^{-7}$ J to $9.17{\times}10^{-7}$ J µg/L (station W013 at RM 6.9E)
- SP-VI: Not sampled
- T-VI (E, M, W): $1.81{\times}10^{-8}$ J to $6.43{\times}10^{-8}$ J µg/L (station W023E at RM 11)
- T-EDI-NS: $2.69{\times}10^{-8}$ J to $9.17{\times}10^{-8}$ J µg/L (station W027 in Multnomah Channel)
- T-EDI-NB: $3.14{\times}10^{-8}$ J to $1.97{\times}10^{-7}$ J µg/L (station W005 at RM 3.9)
- T-EDI-VI: $4.30{\times}10^{-8}$ J to $3.27{\times}10^{-7}$ J µg/L (station W005 at RM 3.9).

TCDD TEQ concentrations in samples collected during stormwater-influenced flow conditions ranged as follows:

- SP-NS: $7.77{\times}10^{-8}$ J to $1.36{\times}10^{-7}$ J µg/L (station W035 in Swan Island Lagoon)
- SP-NB: $1.01{\times}10^{-7}$ J to $2.12{\times}10^{-7}$ J µg/L (station W033 at RM 7W)
- SP-VI: Not sampled
- T-VI (E, M, W): $1.33{\times}10^{-8}$ J to $2.78{\times}10^{-7}$ J µg/L (station W023E at RM 11)

- T-EDI-NS: 3.73×10^{-8} J to 1.38×10^{-7} J µg/L (station W027 in Multnomah Channel)
- T-EDI-NB: 7.77×10^{-8} J to 1.09×10^{-7} J µg/L (station W027 in Multnomah Channel)
- T-EDI-VI: Not sampled.

TCDD TEQ concentrations in samples collected during high-flow conditions, ranged as follows:

- SP-NS: 5.09×10^{-8} J to 1.68×10^{-7} J µg/L (station W035 in Swan Island Lagoon)
- SP-NB: 4.91×10^{-8} J to 1.49×10^{-7} J µg/L (station W035 in Swan Island Lagoon)
- SP-VI: Not sampled
- T-VI (E, M, W): 1.13×10^{-8} J to 9.12×10^{-8} J µg/L (station W023-M at RM 11)
- T-EDI-NS: 2.38×10^{-8} J to 6.73×10^{-8} J µg/L (station W027 in Multnomah Channel)
- T-EDI-NB: 1.65×10^{-8} J to 6.82×10^{-8} J µg/L (station W005 at RM 3.9)
- T-EDI-VI: Not sampled.

5.4.5.3 Spatial Distribution of Total PCDD/Fs and TCDD TEQ

There are no DEQ WQC for total PCDD/Fs. None of the sample results exceed the MCL for TCDD TEQ (3.0×10^{-5} µg/L) or the DEQ chronic AWQC for aquatic life (3.8×10^{-5} µg/L). All the sample results exceed the DEQ TCDD WQC for human health (5.1×10^{-10} µg/L) by 1 to 3 orders of magnitude. However, this value is significantly lower than analytical detection limits. The majority of the highest total concentrations ($>1.0 \times 10^{-7}$ µg/L) were associated with both transect and single-point samples collected predominantly during low-flow and stormwater-induced flow conditions.

The highest TCDD TEQ concentrations ($>1.0 \times 10^{-7}$ µg/L) were detected at the following stations during low-flow events:

- W005 (transect at RM 3.9)
- W011 (transect at RM 6.3)
- W013 (RM 6.7E)
- W015 (RM 6.9W).

The highest TCDD TEQ concentrations ($>1.0 \times 10^{-7}$ µg/L) during the stormwater-influenced flow event were detected at the following stations:

- W005 (transect at RM 3.9)
- W023 (RM 11E)

- W027 (transect in Multnomah Channel)
- W032 (RM 6.7E)
- W033 (RM 7W)
- W035 (Swan Island Lagoon).

The only samples with relatively high TCDD TEQ concentrations were collected during high-flow events in Swan Island Lagoon (SP-NS, 1.7×10^{-7} and SP-NB, 1.5×10^{-7} µg/L).

5.4.6 Total DDx in Surface Water

Total DDx data are summarized in Tables 5.4-6 through 5.4-11. Transect samples are summarized by flow event in Tables 5.4-6, 5.4-8, and 5.4-10. Single-point samples are summarized by flow event in Tables 5.4-7a-d, 5.4-9a-d, and 5.4-11a-d. All total DDx surface water sample results are presented in Table 5.4-15 by sample event and sample location.

Dissolved and particulate total DDx concentrations in surface water XAD columns and filters and total DDx concentrations from the peristaltic pumps are presented in bar graphs by flow event on Figure 5.4-20 and by river mile/channel position on Figure 5.4-21a-b.

Total DDx concentrations at the transect locations as a function of flow rate are presented on Figure 5.4-22. The data points presented in this figure are averages of all data points collected at a particular transect for each measured flow event.

Figures 5.4-23a-b present a scatter plot of all detected total DDx surface water data. Note the symbols and colors indicate the sample type—point vs. transect—and the general flow conditions of the sampling event—low flow, stormwater-influenced, or high flow.

5.4.6.1 Total DDx Data

Total DDx contaminants were analyzed by USEPA Method 8081A in 84 of the total 180 peristaltic samples collected, including 59 SP-NB samples, 16 SP-NS samples, 8 SP-VI samples, and 1 T-EDI-NS sample. High-volume surface water samples (XAD samples) were analyzed for total DDx contaminants by AXYS Method MLA-028 (Rev 1 or 2) in 93 of the total 121 XAD samples collected, including 26 SP-NB samples, 11 SP-NS samples, 12 T-EDI-NB samples, 12 T-EDI-NS samples, 9 T-EDI-VI samples, and 23 T-VI (E, M, W) samples.

Total DDx contaminants were not detected in the majority of the peristaltic samples (55 of 84 non-detect samples) with detection limits ranging from 4.72×10^{-4} to 0.0016 µg/L. Most of the detection limits are less than the chronic Oregon WQC for aquatic life (0.001 µg/L for 4,4'-DDT); only four of the non-detect samples exceed 0.001 µg/L.

Total DDx contaminants were detected in all but one (LW3-W3023-M-F) of the XAD samples (mid channel, filter sample).

5.4.6.2 Total DDx Relationships to River Flow Conditions

Total DDx concentrations are subsequently listed as measured in the peristaltic samples or calculated as the sum of the dissolved (XAD column) and particulate (XAD filter) concentrations. Total DDx concentrations in samples collected during low-flow conditions ranged as follows (the station listed is for the maximum):

- SP-NB:4.92×10^{-5} J to 0.0187 J µg/L (station W001 at RM 2E)
- SP-NS: Not sampled
- SP-VI: All non-detected peristaltic samples
- T-EDI-NB: 6.87×10^{-5} J to 5.46×10^{-4} J µg/L (station W005 at RM 3.9)
- T-EDI-NS: 6.03×10^{-5} J to 5.00×10^{-4} J µg/L (station W027 at Multnomah Channel)
- T-VI (E, M, W): 8.91×10^{-5} J to 3.22×10^{-4} J µg/L (station W025-W at RM 2)
- T-EDI-VI: 4.28×10^{-5} J to 2.37×10^{-4} J µg/L (station W011 at RM 6.3).

Total DDx concentrations in samples collected during stormwater-influenced flow conditions ranged as follows (the station listed is for the maximum):

- SP-NB: 1.01×10^{-4} J to 0.0047 J µg/L (station W037 at RM 9.6W)
- SP-NS: 7.67×10^{-5} J to 0.0029 J µg/L (station W031 at RM 6.1W)
- SP-VI: Not sampled
- T-EDI-NB: 9.11×10^{-5} J to 2.01×10^{-4} J µg/L (station W011 at RM 6.3)
- T-EDI-NS: 5.8×10^{-5} J to 0.0019 µg/L (station W027 in Multnomah Channel)
- T-VI (E, M, W): 3.32×10^{-5} J µg/L to 1.84×10^{-4} J µg/L (station W025-W at RM 2)
- T-EDI-VI: Not sampled.

Total DDx concentrations in samples collected during high-flow conditions ranged as follows (the station listed is for the maximum):

- SP-NB: 1.80×10^{-4} J to 0.00205 J µg/L (station W037 at RM 9.6W)
- SP-NS: 1.70×10^{-4} J to 9.60×10^{-4} J µg/L (station W029 at RM 4.4W)
- SP-VI: Not sampled
- T-EDI-NB: 3.75×10^{-4} J to 5.78×10^{-4} J µg/L (station W005 at RM 3.9)
- T-EDI-NS: 3.46×10^{-4} J to 5.35×10^{-4} J µg/L (station W005 at RM 3.9)

- T-VI (E, M, W): 1.62×10^{-4} J to 6.18×10^{-4} J µg/L (station W023-E at RM 11)
- T-EDI-VI: Not sampled.

With the exception of the highest total DDx concentrations that were measured at RM 6.9 and 7.2 and a single high concentration measured at RM 2 (March 2005), the range of total DDx concentrations detected was fairly consistent. Total DDx concentrations in surface water transect stations (Figures 5.4-23a-b) were generally higher in high-flow samples than in those associated with the low-flow and stormwater-influenced samples.

5.4.6.3 Total DDx Spatial Distribution

Results from 20 sample stations exceeded the chronic Oregon WQC for aquatic life (0.001 µg/L for 4,4'-DDT) by a factor of 1 to 19.

The highest concentrations (>0.003 µg/L) were detected at the following stations during low-flow events:

- W001 (RM 2E)
- W015 (RM 6.9W) on three dates
- W016 (RM 7.2W).

The highest concentrations (>0.003 µg/L) were detected at the following stations during the stormwater-influenced flow event:

- W030 (RM 5.5E)
- W037 (RM 9.6W).

The highest XAD concentrations were measured in single-point samples collected during low-flow conditions near the middle of the Study Area at RM 6.9W (station W015; 0.00767 µg/L) and RM 7.2W (station W016; 0.00976 µg/L). Excluding these higher concentrations, the overall range of observed concentrations across the Study Area and upstream to RM 16 was fairly consistent. High-flow transect samples showed upstream concentrations that were greater than low-flow and stormwater-influenced concentrations in the Study Area (Figure 5.4-22). The stormwater-influenced and low-flow samples increased between RM 11 and 6; and decreased downstream.

5.4.7 Total PAHs in Surface Water

Total PAHs data are summarized in Tables 5.4-6 through 5.4-11. Transect samples are summarized by flow event in Tables 5.4-6, 5.4-8, and 5.4-10. Single point samples are summarized by flow event in Tables 5.4-7a-d, 5.4-9a-d, and 5.4-11a-d. All PAH surface water samples are presented in Table 5.4-16 by sample event and sample location.

Dissolved and particulate total PAHs concentrations in surface water XAD columns and filters and total PAHs concentrations from the peristaltic pump samples are presented in bar graphs by flow event in Figure 5.4-24 and by river mile/channel position in Figure 5.4-25a-b.

Total PAHs concentrations at the transect locations as a function of flow rate are presented in Figure 5.4-26. The values presented in this figure are averages of all measurements collected at a particular transect for each measured flow event.

Figure 5.4-27 presents a scatter plot of all detected total PAHs surface water data. Note the symbols and colors indicate the sample type—point vs. transect—and the general flow conditions of the sampling event—low flow, stormwater-influenced, or high flow.

5.4.7.1 Total PAHs Data

Total PAHs were analyzed by HRGC/LRMS in 174 of the 180 peristaltic samples[11], including 83 SP-NB, 26 SP-NS, 8 SP-VI, 12 T-EDI-NB, 12 T-EDI-NS, 9 T-EDI-VI samples and 24 T-VI (E, M, W) samples. High-volume surface water samples (XAD samples) were analyzed by HRGC/HRMS in 85 of the total 121 XAD samples, including 22 SP-NB, 7 SP-NS, 12 T-EDI-NB, 12 T-EDI-NS, and 9 T-EDI-VI, and 23 T-VI (E, M, W) samples.

Total PAHs were detected in over half of the peristaltic samples (101 of 174 samples) with detection limits for the non-detects ranging from 0.0065 to 0.043 µg/L. Total PAHs were detected in all the XAD samples (column sample or filter sample or both). The detection limits in non-detect peristaltic samples were well below the MCL for benzo(a)pyrene (0.2 µg/L). The highest detected PAH value of 7.4 µg/L (station W031 at RM 6.1) is well below the Oregon-specific water quality guidance for freshwater aquatic life for the only two PAHs for which there is any such guidance (acenaphthene: 520 µg/L; and naphthalene: 620 µg/L).

Detected total PAHs concentrations are subsequently listed as measured in the peristaltic samples or calculated as the sum of the dissolved (XAD column) and particulate (XAD filter) concentrations.

5.4.7.2 Total PAHs Relationships to River Flow Conditions

Detected PAHs concentrations in samples collected during low-flow conditions ranged as follows (the station listed is for the maximum):

- SP-NB: 0.0026 J to 2.5 J µg/L (station W012 at RM 6.3W)
- SP-NS: Not sampled

[11] Sample events could involve replicate samples, and for XAD sampling, the column and filter samples together are counted as one sample. These counts are strictly of sample events, and the values listed here are with replicates averaged together.

- SP-VI: 0.0049 J to 0.0413 J µg/L (station W020 at RM 9.1 in Swan Island Lagoon)
- T-EDI-NB: 0.0045 J to 0.066 J µg/L (station W027 at Multnomah Channel)
- T-EDI-NS: 0.0061 J to 0.048 J µg/L (station W027 at Multnomah Channel)
- T-VI (E, M, W): 0.0039 J to 0.037 J µg/L (station W025-E at RM 2).
- T-EDI-VI: 0.0061 J to 0.066 J µg/L (station W023 at RM 11).

PAHs concentrations in samples collected during stormwater-influenced flow conditions ranged as follows (the station listed is for the maximum):

- SP-NB: 0.005 J to 0.12 J µg/L (station W033 at RM 7W)
- SP-NS: 0.0060 J to 0.051 J µg/L (station W033 at RM 7W)
- SP-VI: Not sampled
- T-EDI-NB: 0.0041 J to 0.068 J µg/L (station W027 at RM 2.9W)
- T-EDI-NS: 0.0087 J to 0.039 J µg/L (station W005 at RM 3.9)
- T-VI (E, M, W): 0.00279 J µg/L to 0.023 J µg/L (Station W025-E at RM 2)
- T-EDI-VI: Not sampled.

PAHs concentrations in samples collected during high-flow conditions ranged as follows (the station listed is for the maximum):

- SP-NB: 0.010 J to 7.4 J µg/L (station W031 at RM 6.1W)
- SP-NS: 0.0047 J to 0.27 J µg/L (station W036 at RM 8.6W)
- SP-VI: Not sampled
- T-EDI-NB: 0.0087 J to 0.023 µg/L (station W005 at RM 3.9)
- T-EDI-NS: 0.0064 J to 0.021 J µg/L (station W005at RM 3.9)
- T-VI (E, M, W): 0.0026 J to 0.059 J µg/L (station W005 at RM 3.9)
- T-EDI-VI: Not sampled.

PAHs concentrations were generally higher in low-flow samples as compared to the high-flow and stormwater-influenced flow samples, suggesting that inflow concentrations at high flow rates overwhelm local effects and dilute the PAHs concentrations (Figure 5.4-24). For all but stormwater events, the transect samples (Figure 5.4-26) show slightly increased concentrations between the RM 16 and 11 transects, indicating there may be inputs of PAHs to the system in this reach. Some events—three of the four low-flow sampling events (November 2004, July 2005, and September 2006), one high-flow event (January 2006), and the stormwater event (November 2006)—show increases in concentrations between RM 11 and 6. However, the March 2005 low-flow event did not show this same trend. Two of the low-flow events (July 2005 and September 2006), the stormwater events (November 2006), and one of the high-flow events (February 2007) show increasing concentrations between RM 6 and 4.

5.4.7.3 Spatial Distribution of Total PAHs

Elevated sample concentrations for total PAHs were recorded at the following stations:

- W031 (RM 6.1W) 7.4 µg/L (February 2007, high flow)
- W012 (RM 6.3W) 2.5 µg/L (July 2005, low flow)
- W012 (RM 6.3W) 1.3 µg/L (November 2004, low flow)
- W021 (RM 8.7 in Swan Island Lagoon) 0.29 µg/L (July 2005, low flow)
- W036 (RM 8.6W) 0.27 µg/L (February 2007, high flow)
- W015 (RM 6.9W) 0.23 µg/L (July 2005, low flow).

All but the last of these were measured in peristaltic samples. The first three appear to be outliers on the distribution of peristaltic samples. All measured concentrations are below the two DEQ guidance values for freshwater aquatic life (acenaphthene: 520 µg/L; and naphthalene: 620 µg/L).

5.4.8 BEHP in Surface Water

BEHP data are summarized in Tables 5.4-6 through 5.4-11. Transect samples are summarized by flow event in Tables 5.4-6, 5.4-8, and 5.4-10. Single-point samples are summarized by flow event in Tables 5.4-7a-d, 5.4-9a-d, and 5.4-11a-d. All BEHP surface water sample results are presented in Table 5.4-17 by sample event and sample location.

Dissolved and particulate BEHP concentrations in surface water XAD columns and filters and BEHP concentrations from the peristaltic pumps are presented in bar graphs by flow event and by river mile/channel position on Figures 5.4-28 and 5.4-29a-b, respectively.

BEHP concentrations at the transect locations as a function of flow rate are presented on Figure 5.4-30. The data points presented in this figure are averages of all data points collected at a particular transect for each measured flow event.

Figure 5.4-31 presents a scatter plot of all detected BEHP surface water data. Note the symbols and colors indicate the sample type—point vs. transect—and the general flow conditions of the sampling event—low flow, stormwater-influenced, or high flow.

5.4.8.1 BEHP Data

BEHP was analyzed by USEPA Methods 8270C or 525.2 in 173 of the total 180 peristaltic samples collected, including 82 SP-NB samples, 26 SP-NS samples, 8 SP-VI samples, 12 T-EDI-NB samples, 12 T-EDI-NS samples, 9 T-EDI-VI samples and 24 T-VI (E, M, W) samples. BEHP was analyzed in high-volume surface water samples (XAD samples) by AXYS Method MLA-027 Rev 01 in 24 of the total 121 XAD samples collected, including 15 SP-NB samples and 9 T-VI (E, M, W) samples.

BEHP was not detected in the majority of the peristaltic samples (157 of 173 samples) with detection limits ranging from 0.098 to 4.1 µg/L.

Detections of BEHP were limited to 15 samples collected during the Round 3A sampling event at the following stations:

- W005 (T-EDI-NS and T-EDI-NB; RM 3.9)
- W011 (T-EDI-NB; RM 6.3)
- W023 (T-VI; RM 11 M)
- W024 (T-EDI-NB; RM 16)
- W025 (T-VI; RM 2E and W)
- W027 (T-EDI-NB; Multnomah Channel)
- W029 (SP-NB; RM 4.4W)
- W032 (SP-NB; RM 6.7E)
- W033 (SP-NS; RM 7W)
- W036 (SP-NS; RM 8.6W).

Detected BEHP concentrations in peristaltic samples ranged from 0.7 to 6.8 J µg/L. During low-flow conditions, BEHP was detected in four samples at concentrations ranging from 0.7 to 1.5 µg/L (T-VI (E, M, W) sample; station W025E at RM 2). During stormwater-influenced flow conditions, BEHP was detected in one T-EDI-NB sample at a concentration of 6.8 J µg/L (station W005 at RM 3.9). During high-flow conditions, BEHP was detected in 11 samples at concentrations ranging from 0.98 J to 3.5 J µg/L (SP-NB sample; station W032 at RM 6.7E).

BEHP concentrations, calculated as the sum of the dissolved (XAD column) and particulate (XAD filter) concentrations, were detected in 9 of 24 samples, all collected during low-flow conditions. BEHP concentrations in these samples ranged as follows:

- SP-NB: 0.0078 J to 0.033 µg/L (station W015 at RM 6.9W)
- T-EDI-VI: 0.0091 J to 0.023 J µg/L (station W023 at RM 11)
- SP-NS, SP-VI, T-EDI-NS, T-EDI-NB: Not sampled with XAD.

5.4.8.2 BEHP Relationship to River Flow Conditions

Detected BEHP concentrations and frequencies were relatively consistent regardless of flow rate. The frequency of detection was 5 percent for low-flow event peristaltic sampling results; 24 percent for high-flow event peristaltic sampling results; 3 percent for stormwater flow peristaltic sampling events; and 38 percent for low-flow event XAD sampling results.

Detected BEHP concentrations in low-flow peristaltic samples ranged from 0.7 to 1.5 µg/L (station W025E at RM 2) in September 2006. Detected BEHP concentrations in high-flow peristaltic samples ranged from 0.98 J to 3.5 J µg/L (station W032 at RM 6.9E) in February 2007. BEHP was detected in only 1 of 37 stormwater-influenced flow samples at a concentration of 6.8 J µg/L (station W005 at RM 3.9) in November 2006.

Detected BEHP concentrations in low-flow XAD samples ranged from 0.0078 J to 0.033 µg/L (station W015 at RM 6.9W).

5.4.8.3 Spatial Distribution of BEHP

One sample result exceeded the MCL for BEHP (6.0 µg/L). All the detected peristaltic and three detected XAD samples exceeded the DEQ human health criteria of 0.2 µg/L. The highest concentrations (>3.0 µg/L) were detected at the following stations:

- W005 (RM 3.9)
- W032 (RM 6.9E).

The next highest concentrations (>1.5 µg/L but <3 µg/L) were detected at the following stations during high-flow conditions:

- W011 (RM 6.3)
- W024 (RM 16)
- W025 (RM 2E)
- W029 (RM 4.4W)
- W036 (RM 8.6W).

5.4.9 Total Chlordanes in Surface Water

Total chlordanes data are summarized in Tables 5.4-6 through 5.4-11. Transect samples are summarized by flow event in Tables 5.4-6, 5.4-8, and 5.4-10. Single-point samples are summarized by flow event in Tables 5.4-7a-d, 5.4-9a-d, and 5.4-11a-d. All total chlordanes surface water sample results are presented in Table 5.4-18 by sample event and sample location.

Total chlordanes concentrations in surface water XAD columns and filters as well as concentrations from the peristaltic pumps are presented in bar graphs by low-flow stormwater-influenced, or high-flow events and by river mile/channel position on Figures 5.4-32 and 5.4-33a-b, respectively.

Total chlordanes concentrations at the transect locations as a function of flow rate are presented on Figure 5.4-34. The data points presented in this figure are averages of all data points collected at a particular transect for each measured flow event.

Figure 5.4-35 presents a scatter plot of detected total chlordanes surface water data. Note the symbols and colors indicate the sample type—point vs. transect—and the general flow conditions of the sampling event—low flow, stormwater-influenced, or high flow.

5.4.9.1 Total Chlordanes Data

Total chlordanes were analyzed by USEPA Method 8081A for 84 of 180 peristaltic samples collected. High-volume surface water samples (XAD samples) were analyzed for total chlordanes by the AXYS method for pesticides for 93 of 121 XAD samples collected.

Total chlordanes were not detected in the majority of the peristaltic samples (78 non-detects of 84 samples) with detected total chlordanes concentrations ranging from 2.90×10^{-4} to 0.0021 µg/L and detection limits for not detected results ranging from 4.72×10^{-4} to 0.0024 µg/L. Total chlordanes were detected in all 93 XAD column (dissolved) samples, with detected concentrations ranging from 6.72×10^{-6} to 5.57×10^{-5} µg/L. Total chlordanes were detected in XAD (column + filter) samples at concentrations ranging from 7.32×10^{-6} to 2.41×10^{-4} µg/L. All of these detected and not detected results are below the acute (2.4 µg/L) and chronic (0.0043 µg/L) Oregon WQC for aquatic life as well as the MCL (2 µg/L). All of the peristaltic detected and not detected results are greater than the Oregon WQC for human health (8.10×10^{-5} µg/L) that is protective of drinking water plus the consumption of organisms. The majority of the XAD samples, calculated as the sum of the XAD column and XAD filter, are less than this criterion; only six sample results exceeded the criterion, with concentrations ranging from 8.34×10^{-5} to 2.41×10^{-4} µg/L. These results suggest that the XAD samples analyzed using the AXYS method for pesticides achieved sufficiently low detection limits to determine that total chlordanes are below applicable human health and ecological criteria in the majority of samples.

5.4.9.2 Total Chlordanes Relationship to River Flow Conditions

Detected total chlordanes concentrations were relatively consistent, with concentrations slightly higher during high flow conditions. A total of 12 samples (6 peristaltic, 6 XAD) exceed the DEQ human health criterion of 8.1×10^{-5} µg/L. Of the samples that exceed the criterion, 8 are from the high-flow events conducted in February and March 2007, and there are 2 each from low-flow and stormwater-influenced events.

Detected total chlordanes concentrations in samples collected during low-flow conditions ranged as follows (the station listed is for the maximum):

- SP-NB: 1.73×10^{-5} J to 0.0021 µg/L (station W002, RM 2W)
- SP-NS: Not sampled

- SP-VI: Not detected
- T-EDI-NB: 2.23×10^{-5} J to 5.88×10^{-5} J µg/L (station W005, RM 3.9)
- T-EDI-NS: 2.27×10^{-5} J to 4.48×10^{-5} J µg/L (station W027i, RM 2.9W)
- T-VI (E, M, W): 2.98×10^{-5} J to 3.33×10^{-5} J µg/L (station W023-E, RM 11)
- T-EDI-VI: 1.34×10^{-5} to 3.70×10^{-5} µg/L (station W011, RM 6.3).

Detected total chlordanes concentrations in samples collected during high-flow conditions ranged as follows (the station listed is for the maximum):

- SP-NB: 4.66×10^{-5} to 6.0×10^{-4} µg/L(station W030, RM 5.5E)
- SP-NS: 4.77×10^{-5} to 5.1×10^{-4} µg/L (station W030, RM 5.5E)
- SP-VI: Not sampled
- T-EDI-NB: 4.83×10^{-5} to 9.43×10^{-5} µg/L (station W005, RM 3.9)
- T-EDI-NS: 3.84×10^{-5} to 9.07×10^{-5} µg/L (station W005, RM 3.9)
- T-VI (E, M, W): 3.36×10^{-5} to 9.11×10^{-5} µg/L (station W023-E, RM 11)
- T-EDI-VI: Not sampled.

Detected total chlordanes concentrations in samples collected during stormwater-influenced conditions ranged as follows (the station listed is for the maximum):

- SP-NB: 1.06×10^{-5} to 3.61×10^{-5} µg/L (station W033, RM 7W)
- SP-NS: 7.32×10^{-6} to 0.0016 µg/L (station W036, RM 8.6W)
- SP-VI: Not sampled
- T-EDI-NB: 2.12×10^{-5} to 3.66×10^{-5} µg/L (station W027 in Multnomah Channel)
- T-EDI-NS: 1.66×10^{-5} to 3.76×10^{-5} µg/L (station W027 in Multnomah Channel)
- T-VI (E, M, W): 1.34×10^{-5} to 2.14×10^{-5} µg/L (station W023-E at RM 11)
- T-EDI-VI: Not sampled.

5.4.9.3 Spatial Distribution of Total Chlordanes

None of the sample results exceed the 2 µg/L drinking water MCL for total chlordanes, or the DEQ ecological acute (2.4 µg/L) or chronic (0.0043 µg/L) criteria for the protection of aquatic life. Each of the four detected concentrations from peristaltic samples exceed the DEQ WQC for human health (8.10×10^{-5} µg/L). Detection limits were higher for the peristaltic samples than the XAD samples. The samples with concentrations greater than the human health criterion were collected at the following stations:

- W002 (RM 2.2W)

- W029 (RM 4.4W)
- W030 (RM 5.5E, NS and NB)
- W036 (RM 8.6W)
- W038 (RM 9.9E).

The sample from station W002 was collected during the low-flow event conducted in July 2005, and the samples from stations W029 and W030 were collected during the high-flow event conducted in March 2007. The samples from stations W036 andW038 were collected during the stormwater event conducted on November 2006.

Lower detection limits were achieved for the XAD samples. Total chlordanes were detected in each of the 93 XAD samples with concentrations in 6 samples slightly exceeding the AWQC for human health (8.10×10^{-5} µg/L). The samples were collected at the following stations:

- W005 (RM 3.9) (two samples)
- W015 (RM 6.9W)
- W023-E (RM 11E)
- W031 (RM 6.1W)
- W033 (RM 7W).

The sample from station W015 was collected during low-flow conditions in November 2004. The samples from stations W005 and W023 were collected during high-flow conditions in March 2007. The samples from stations W031 and W033 were collected during high-flow conditions in February 2007. The low detection limits for the XAD samples and the low frequency of exceedance of the human health AWQC criterion suggest that specific inputs of total chlordanes do not exist in the Study Area.

5.4.10 Aldrin in Surface Water

Aldrin data are summarized in Tables 5.4-6 through 5.4-11. Transect samples are summarized by flow event in Tables 5.4-6, 5.4-8, and 5.4-10. Single point samples are summarized by flow event in Tables 5.4-7a-d, 5.4-9a-d, and 5.4-11a-d. All aldrin surface water sample results are presented in Table 5.4-19 by sample event and sample location.

Dissolved and particulate aldrin concentrations in surface water XAD columns and filters and aldrin concentrations from the peristaltic pumps are presented in bar graphs by flow event type on Figure 5.4-36 and by river mile/channel position on Figures 5.4-37a-b.

Aldrin concentrations at the transect locations as a function of flow rate are presented on Figures 5.4-38. The data points presented in this figure are averages of all data points collected at a particular transect for each measured flow event.

Figure 5.4-39 presents a scatter plot of all detected aldrin surface water data. Note the symbols and colors indicate the sample type—point vs. transect—and the general flow conditions of the sampling event—low flow, stormwater-influenced, or high flow.

5.4.10.1 Aldrin Data

Aldrin was measured by USEPA Method 8081A in 84 of the total 180 peristaltic sample events, including 59 SP-NB, 16 SP-NS, 8 SP-VI, 0 T-EDI-NB, and 1 T-EDI-NS samples. High-volume surface water samples (XAD samples) were analyzed by HRGC/HRMS in 93 of the total 121 XAD samples collected, including 26 SP-NB, 11 SP-NS, 12 T-EDI-NB, 12 T-EDI-NS, 9 T-EDI-VI, and 23 T-VI (E, M, W) samples.

With one exception, Aldrin was not detected in any of the peristaltic samples, with detection limits ranging from 5.7×10^{-5} to 0.0058 µg/L; all but 3 of these detection limits were less than 0.001 µg/L. The single detected sample was a SP-NB measurement of 0.0052 µg/L at W030 (RM 5.5E) during high flow. This value was 319 times higher than the highest detected sample in the XAD data, and the non-detect SP-NS sample at the same location and time had the (higher) detection limit of 0.0058 µg/L. For comparison, the DEQ WQC for human health is 5.0×10^{-6} µg/L.

Aldrin concentrations, calculated as the sum of the dissolved (XAD column) and particulate (XAD filter) concentrations, were detected in 81 of the 93 samples, with detection limits in the non-detects ranging from 6.13×10^{-7} to 6.2×10^{-6} µg/L.

5.4.10.2 Aldrin Relationship to River Flow Conditions

Detected aldrin concentrations in samples collected during low-flow conditions ranged as follows (the station listed is for the maximum):

- SP-NB: 3.1×10^{-7} J to 1.63×10^{-5} J µg/L (station W013 at RM 6.7E)
- SP-NS: Not sampled
- SP-VI: Not sampled
- T-EDI-NB: 4.39×10^{-6} J to 6.62×10^{-6} J µg/L (station W005 at RM 3.9)
- T-EDI-NS: 1.79×10^{-6} J to 4.6×10^{-6} J µg/L (station W027 at Multnomah Channel)
- T-EDI-VI: 2.96×10^{-7} J to 2.74×10^{-6} J µg/L (station W011-E at RM 6.3)
- T-VI (E, M, W): 1.86×10^{-6} J to 4.09×10^{-6} J µg/L (station W025E at RM 2).

Detected aldrin concentrations in samples collected during stormwater-influenced flow conditions ranged as follows (the station listed is for the maximum):

- SP-NB: 1.41×10^{-6} J to 3.67×10^{-6} J µg/L (station W033 at RM 7W)
- SP-NS: 6.35×10^{-7} J to 4.84×10^{-6} J µg/L (station W033 at RM 7W)
- SP-VI: Not sampled
- T-EDI-NB: 2.01×10^{-6} J to 5.75×10^{-6} J µg/L (station W027 at Multnomah Channel)
- T-EDI-NS: 2.04×10^{-6} J to 2.63×10^{-6} J µg/L (station W027 at Multnomah Channel)
- T-EDI-VI: Not sampled
- T-VI (E, M, W): 1.1×10^{-6} J to 3.26×10^{-6} J µg/L (station W025-W at RM 2).

Detected aldrin concentrations in samples collected during high-flow conditions ranged as follows (the station listed is for the maximum):

- SP-NB:5.14×10^{-7} J to 0.0052 µg/L (station W030 at RM 5.5E)
- SP-NS: 2.16×10^{-6} J to 3.52×10^{-6} J µg/L (station W035 at RM 8.5 in Swan Island Lagoon)
- SP-VI: Not sampled
- T-EDI-NB: 2.81×10^{-6} J to 4.75×10^{-6} J µg/L (station W027 at Multnomah Channel)
- T-EDI-NS: 2.57×10^{-6} J to 4.0×10^{-6} J µg/L (station W005 at RM 3.9)
- T-EDI-VI: Not sampled
- T-VI (E, M, W): 1.24×10^{-6} J to 5.99×10^{-6} J µg/L (station W025-M at RM 2).

Aldrin concentrations were slightly lower in the low flow than in the high-flow XAD samples. Comparison with stormwater-influenced samples is difficult due to the high frequency of non-detects.

Concentration trends along the river were examined by using T-VI (E, M, W) XAD samples, either single samples (November 2004, March 2005, July 2005, January 2006, January 2007, March 2007) or averages of east, west, and middle samples (September 2006, November 2006). Low-flow samples are consistent in showing a decreasing concentration trend between RM 6 and 1 in the three events with suitable samples (November 2004, March 2005, July 2005), consistent with no sources in this range. The high-flow event of January 2006 and the stormwater event of November 2006 indicate an increasing concentration between RM 3 and 1. One low-flow event (September 2006) and one high-flow event (January 2007) showed an increase in concentration between RM 11 and 2, suggesting sources within that range, while a second high-flow event (March 2007) showed a decrease in concentration.

5.4.10.3 Spatial Distribution of Aldrin

Five detected XAD samples exceeded the DEQ criterion for human health (water + organisms) of 5.0×10^{-6} µg/L:

- W011 (RM 6.3 T-EDI-NB)
- W027 (Multnomah Channel T-EDI-NB)
- W025 (RM 2M T-VI)
- W005 (RM 3.9 T-EDI-NB)
- W015 (RM 6.9W SP-NB).

The highest XAD concentration measurement of 1.63×10^{-5} µg/L was in a SP-NB measurement at W015 (RM 6.9W) but the nearest available measurements in W032 and W033 and downriver in W011 do not suggest an area of elevated concentrations.

5.4.11 Dieldrin in Surface Water

Dieldrin data are summarized in Tables 5.4-6 through 5.4-11. Transect samples are summarized by flow event in Tables 5.4-6, 5.4-8, and 5.4-11. Single-point samples are summarized by flow event in Tables 5.4-7a-d, 5.4-9a-d, and 5.4-11a-d. All dieldrin surface water sample results are presented in Table 5.4-20 by sample event and sample location.

Dieldrin concentrations in surface water XAD columns and filters and dieldrin concentrations from the peristaltic pumps are presented in bar graphs by flow event and by river mile/channel position on Figures 5.4-40 and 5.4-41a-b, respectively.

Dieldrin concentrations at the transect locations as a function of flow rate are presented on Figure 5.4-42. The data points presented in this figure are averages of all data points collected at a particular transect for each measured flow event.

Figure 5.4-43 presents a scatter plot of all detected dieldrin surface water data. Note the symbols and colors indicate the sample type—point vs. transect—and the general flow conditions of the sampling event—low flow, stormwater-influenced, or high flow.

5.4.11.1 Dieldrin Data

Dieldrin was measured by USEPA Method 8081A in 84 of the total 180 peristaltic samples, including 59 SP-NB, 16 SP-NS, 8 SP-VI, 0 T-EDI-NB, and 1 T-EDI-NS samples. High-volume surface water samples (XAD samples) were analyzed by HRGC/HRMS in 93 of the total 121 XAD samples collected, including 26 SP-NB, 11 SP-NS, 12 T-EDI-NB, 12 T-EDI-NS, 9 T-EDI-VI and 23 T-VI (E, M, W) samples.

The range of detected concentrations in the three SP-NB peristaltic samples in which dieldrin was detected was 0.0010 to 0.0012 µg/L (maximum value during high flow at both W036, RM 8.6 and W028, RM 3.6E, January 2007).

Dieldrin concentrations, calculated as the sum of the XAD column and XAD filter concentrations, ranged from 1.67×10^{-5} to 3.84×10^{-4} µg/L.

5.4.11.2 Dieldrin Relationships to River Flow Conditions

Where detected, dieldrin concentrations were relatively consistent in both low-flow and high-flow samples, and were also relatively similar across sample types. The range of dieldrin concentrations by sample type are presented below.

Dieldrin concentrations in samples collected during low-flow conditions ranged as follows (the station listed is for the maximum):

- SP-NB: 2.27×10^{-5} to 6.25×10^{-5}µg/L (station W015 at RM 6.9W)
- SP-NS: Not sampled
- SP-VI: Not sampled.
- T-EDI-NB: 3.48×10^{-5} J to 4.87×10^{-5} J µg/L (station W005 at RM 3.5)
- T-EDI-NS: 3.53×10^{-5} J to 4.70×10^{-5} J µg/L (station W005 at RM 3.5)
- T-EDI-VI:1.67×10^{-5} J to 4.34×10^{-5} J µg/L (station W011 at RM 6.3)
- T-VI (E, M, W): 3.77×10^{-5} J to 4.62×10^{-5} J µg/L (station W023-W at RM 11).

Dieldrin concentrations in samples collected during high-flow conditions ranged as follows (the station listed is for the maximum):

- SP-NB: 1.10×10^{-4} J to 0.0012 J µg/L (station W028 at RM 3.6E)
- SP-NS: 1.08×10^{-4} J to 1.80×10^{-4} J µg/L (station W033 at RM 7W)
- SP-VI: Not sampled
- T-EDI-NB: 9.93×10^{-5} to 1.58×10^{-4} µg/L (station W027 at Multnomah Channel)
- T-EDI-NS: 7.05×10^{-5} to 1.59×10^{-4} J µg/L (station W005 at RM 3.9)
- T-VI (E, M, W): 8.49×10^{-5} to 3.84×10^{-4} µg/L (station W005 at RM 3.9)
- T-EDI-VI: Not sampled.

Dieldrin concentrations in samples collected during stormwater-influenced conditions ranged as follows (the station listed is for the maximum):

- SP-NB: 3.62×10^{-5} J to 5.01×10^{-5} J µg/L (station W031 at RM 6.1W)
- SP-NS: 3.19×10^{-5} J to 4.98×10^{-5} J µg/L (station W031 at RM 6.1)
- SP-VI: Not sampled.
- T-EDI-NB: 3.06×10^{-5} J to 4.82×10^{-5} J µg/L (station W024 at RM 16)
- T-EDI-NS: 3.22×10^{-5} J to 5.37×10^{-5} J µg/L (station W024 at RM 16)

- T-VI (E, M, W): 2.51×10^{-5} J to 3.87×10^{-5} J µg/L (station W023-E at RM 11)
- T-EDI-VI: Not sampled.

5.4.11.3 Spatial Distribution of Dieldrin

All of the surface water samples analyzed for dieldrin exceeded the human health DEQ value developed to be protective of drinking water and consumption of organisms (5.3×10^{-6} µg/L). No sample result exceeded the DEQ dieldrin chronic value for protection of aquatic life (0.056 µg/L).

5.4.12 Arsenic in Surface Water

Arsenic data are summarized in Tables 5.4-6 through 5.4-11. Transect samples are summarized by flow event in Tables 5.4-6, 5.4-8, and 5.4-10. Single-point samples are summarized by flow event in Tables 5.4-7a-d, 5.4-9a-d, and 5.4-11a-d. All total and dissolved arsenic surface water sample results are presented in Tables 5.4-21a-b by sample event and sample location. Dissolved and particulate arsenic concentrations in surface water collected from peristaltic pumps are presented in bar graphs by flow event on Figure 5.4-44 and by river mile/channel position on Figure 5.4-45.

Arsenic concentrations at the transect locations as a function of flow rate are presented on Figure 5.4-46. The data points presented in this figure are averages of all data points collected at a particular transect for each measured flow event.

Figure 5.4-47 presents a scatter plot of all detected arsenic surface water data. Note the symbols and colors indicate the sample type—point vs. transect—and the general flow conditions of the sampling event—low flow, stormwater-influenced, or high flow.

5.4.12.1 Arsenic Data

Peristaltic samples were collected and analyzed by USEPA Method 6020 for total and dissolved arsenic during Rounds 2A and 3A. Dissolved arsenic was detected in 136 (78 percent) of the 174 samples and 157 (90 percent) of 174 total arsenic samples during the Round 2A and 3A sampling events.

Total arsenic concentrations were generally consistent across the entire Study Area during the Round 2A and 3A sampling events. The overall range of detected concentrations for all total arsenic samples was narrow, ranging from 0.254 to 0.745 µg/L, suggesting that there are no specific areas with elevated arsenic concentrations.

5.4.12.2 Arsenic Relationship to River Flow Conditions

Detected arsenic concentrations were relatively consistent regardless of flow rate; however, frequency of detection was significantly reduced during stormwater-influenced events. The frequency of detection was 100 percent for total arsenic and 98 percent for dissolved arsenic for all combined low-flow and high-flow sampling event sample results. The frequency of detection was 58 percent for total arsenic and 13 percent for dissolved arsenic for the stormwater-influenced samples.

While total arsenic concentrations were relatively consistent, in general, they were slightly higher in low-flow sampling events, with concentrations ranging from 0.33 to 0.75 µg/L compared to high-flow sampling events with concentrations ranging from 0.25 to 0.63 µg/L. Twenty-three stormwater-influenced samples displayed a narrow range of detected concentrations between 0.43 to 0.53 µg/L. Dissolved and particulate arsenic concentrations in surface water are depicted in histograms by flow event type on Figure 5.4-44 for high-flow, low-flow, and stormwater-influenced events.

Arsenic concentrations in samples collected during low-flow conditions ranged as follows (the station listed is for the maximum):

- Total arsenic, single point: 0.33 to 0.75 µg/L at station W001 (RM 2E)
- Dissolved arsenic, single point: 0.25 to 0.64 µg/L at station W001 (RM 2E)
- Total arsenic, transect: 0.35 to 0.64 µg/L at station W025-E (RM 2).
- Dissolved arsenic, transect: 0.19 to 0.60 µg/L at station W025-M (RM 2).

Arsenic concentrations in samples collected during high-flow conditions ranged as follows (the station listed is for the maximum):

- Total arsenic, single point: 0.30 to 0.63 J µg/L at station W034 (NS; RM 7.5)
- Dissolved arsenic, single point: 0.19 J to 0.34 J µg/L at station W034 (NS; RM 7.5)
- Total arsenic, transect: 0.25 to 0.54 µg/L at station W005 (RM 4) and station W023 (RM 6.3)
- Dissolved arsenic, transect: 0.18 to 0.28 µg/L at station W027 (NB; Multnomah Channel).

Arsenic concentrations in samples collected during stormwater-influenced conditions ranged as follows (the station listed is for the maximum):

- Total arsenic, single point 0.43 J to 0.53 J µg/L at station W038 (NB; RM 11)
- Dissolved arsenic, single point: 0.38 J to 0.48 µg/L at station W038 (NB; RM 11E)
- Total arsenic, transect: 0.44 to 0.48 J µg/L at station W005 (NB; RM 4)
- Dissolved arsenic, transect: Not detected.

5.4.12.3 Spatial Distribution of Arsenic

All of the total and dissolved arsenic surface water results were less than the drinking water MCL of 10 µg/L, the DEQ human health criterion of 2.1 µg/L, and the DEQ chronic value of 150 µg/L for the protection of aquatic life.

5.4.13 Chromium in Surface Water

Data for chromium in surface water are summarized in Tables 5.4-6 through 5.4-11. Transect samples are summarized by flow event in Tables 5.4-6, 5.4-8, and 5.4-10. Single-point samples are summarized by flow event in Tables 5.4-7a-d, 5.4-9a-d, and 5.4-11a-d. All total and dissolved chromium surface water sample results are presented in Tables 5.4-22a-b by sample event and sample location.

Dissolved and particulate chromium concentrations in surface water collected from peristaltic pumps are presented in bar graphs by flow event on Figure 5.4-48 and by river mile/channel position on Figure 5.4-49.

Figure 5.4-50 is a line plot of transect chromium concentrations in surface water by river mile (RM 2–16). The data points presented in this figure are averages of all data points collected at a particular transect for each measured flow event.

Figure 5.4-51 is a scatter plot of detected chromium concentrations in surface water by river mile (RM 2–16). The symbols and colors indicate the sample type—point vs. transect—and the general flow conditions of the sampling event—low flow, stormwater-influenced, or high flow.

5.4.13.1 Chromium Data

Peristaltic samples were collected and analyzed by USEPA Method 6020 for total and dissolved chromium during Rounds 2A and 3A. Dissolved chromium was detected in 58 of 174 (33 percent) of samples and 112 of 174 (64 percent) of total chromium samples during the Round 2A and 3A sampling events.

Total chromium concentrations were generally consistent across the entire Study Area during the Round 2A and 3A sampling events. The overall range of detected concentrations for all total chromium samples was 0.2 to 1.92 µg/L. The range of detected concentrations of dissolved chromium was narrower, from 0.1 to 0.83 µg/L.

5.4.13.2 Chromium Relationship to River Flow Conditions

In general, total chromium concentrations were slightly lower in samples collected during low-flow sampling events with concentrations ranging from 0.2 to 1.09 µg/L compared to results from high-flow sampling events where total chromium concentrations ranged from 0.58 to 1.92 µg/L. Dissolved chromium concentrations were generally lower in low-flow samples. Detected dissolved chromium concentrations ranged from 0.43 to 0.83 µg/L in high-flow samples and from 0.1 to 0.33 µg/L in low-flow samples.

Forty stormwater-influenced samples were analyzed for total and dissolved chromium. Neither total chromium nor dissolved chromium was detected in any of those samples.

Chromium concentrations in samples collected during low-flow conditions ranged as follows (the station listed is for the maximum):

- Total chromium, single point: 0.2 to 0.91 µg/L at station W004 (RM 3.7E)
- Dissolved chromium, single point: 0.1 to 0.33 µg/L at station W004 (RM 3.7E)
- Total chromium, transect: 0.29 to 1.1 µg/L at station W005 (RM 3.9)
- Dissolved chromium, transect: 0.12 to 0.29 µg/L at station W011 (RM 6.3).

Chromium concentrations in samples collected during high-flow conditions ranged as follows (the station listed is for the maximum):

- Total chromium, single point: 0.7 to 1.9 J µg/L at station W031 (RM 6.1W)
- Dissolved chromium, single point: 0.43 to 0.64 µg/L at station W034 (RM 7.5W)
- Total chromium, transect: 0.58 to 1.7 at station W027 (Multnomah Channel)
- Dissolved chromium, transect: 0.46 to 0.83 µg/L at station W024 (RM 16).

Neither total nor dissolved chromium was detected in any single-point or transect samples collected during the November 2006 stormwater-influenced sampling event.

5.4.13.3 Spatial Distribution of Chromium

All of the total and dissolved chromium surface water results were less than the drinking water MCL of 100 µg/L. DEQ does not have human health or aquatic life criteria for total chromium.

5.4.14 Copper in Surface Water

Copper data are summarized in Tables 5.4-6 through 5.4-11. Transect samples are summarized by flow event in Tables 5.4-6, 5.4-8, and 5.4-10. Single-point samples are summarized by flow event in Tables 5.4-7a-d, 5.4a-d, and 5.4-11a-d. All total and dissolved copper surface water sample results are presented in Tables 5.4-23a-b by sample event and sample location.

Dissolved and particulate copper concentrations in surface water collected from peristaltic pumps are presented in bar graphs by flow event on Figure 5.4-52 and by river mile/channel position on Figure 5.4-53.

Figure 5.4-54 is a line plot of transect copper concentrations in surface water by river mile (RM 2–16). The data points presented in this figure are averages of all data points collected at a particular transect for each measured flow event.

Figure 5.4-55 is a scatter plot of detected copper concentrations in surface water by river mile (RM 2–16). The symbols and colors indicate the sample type—point vs. transect—and the general flow conditions of the sampling event—low flow, stormwater-influenced, or high flow.

5.4.14.1 Copper Data

Peristaltic samples were collected and analyzed by USEPA Method 6020 for total and dissolved copper during Rounds 2A and 3A. Dissolved copper was detected in 99 percent of 174 samples and 100 percent of 174 total copper samples during the Round 2A and 3A sampling events. The overall range of detected concentrations for all total copper samples ranged from 0.65 to 3.68 µg/L.

5.4.14.2 Copper Relationship to River Flow Conditions

Total copper concentrations were generally consistent across the entire Study Area during the Round 2A and 3A sampling events. Concentrations were generally higher in samples collected during the high-flow sampling events, with concentrations ranging from 1.1 to 3.68 µg/L compared to samples collected during low-flow sampling events, with concentrations ranging from 0.68 to 2.09 µg/L. Forty stormwater-influenced samples displayed a narrow range of detections between 0.65 to 1.14 µg/L. Dissolved and particulate copper concentrations in surface water are depicted in histograms by flow event type on Figure 5.4-52 for high-flow, low-flow, and stormwater-influenced events.

Copper concentrations in samples collected during low-flow conditions ranged as follows (the station listed is for the maximum):

- Total copper, single point: 0.68 to 2.1 µg/L at station W004 (RM 3.7)
- Dissolved copper, single point: 0.37 to 1.64 µg/L at station W022 (NB; RM 9.7W)
- Total copper, transect: 0.68 to 1.5 µg/L at station W005 (NB; RM 3.9)
- Dissolved copper, transect: 0.45 to 0.83 J µg/L at station W011 (RM 6.3).

Copper concentrations in samples collected during high-flow conditions ranged as follows (the station listed is for the maximum):

- Total copper, single point: 1.5 to 3.5 µg/L at station W031 (NB; RM 6.1W)
- Dissolved copper, single point: 0.55 to 1.2 µg/L at station W035 (NS; RM 8.5E)
- Total copper, transect: 1.1 to 3.7 J µg/L at station W023 (RM 11)
- Dissolved copper, transect: 0.43 to 2.4 J µg/L at station W023 (RM 11).

Copper concentrations in samples collected during stormwater-influenced conditions ranged as follows (the station listed is for the maximum):

- Total copper, single point: 0.79 to 1.1 µg/L at station W035 (NS; RM 8.5E)
- Dissolved copper, single point: 0.5 to 0.78 µg/L at station W035 (NS; RM 8.5E)
- Total copper, transect: 0.65 to 1.1 µg/L at station W024 (RM 16)
- Dissolved copper, transect: 0.46 to 1.2 µg/L at station W023-M (RM 11).

5.4.14.3 Spatial Distribution of Copper

All of the total and dissolved copper surface water results were less than the drinking water MCL of 1,300 µg/L and the DEQ human health threshold value of 1,300 µg/L developed to be protective of drinking water and consumption of organisms.

These results do not suggest potential source areas for copper.

5.4.15 Zinc in Surface Water

Data for zinc in surface water are summarized in Tables 5.4-6 through 5.4-11. Transect samples are summarized by flow event in Tables 5.4-6, 5.4-8, and 5.4-10. Single-point samples are summarized by flow event in Tables 5.4-7a-d, 5.4-9a-d, and 5.4-11a-d. All total and dissolved zinc surface water sample results are presented in Tables 5.4-24a-b by sample event and sample location.

Dissolved and particulate zinc concentrations in surface water collected from peristaltic pumps are presented in bar graphs by flow event on Figure 5.4-56 and by river mile/channel position on Figure 5.4-57a-b.

Figure 5.4-58 is a line plot of transect zinc concentrations in surface water by river mile (RM 2–16). The data points presented in this figure are averages of all data points collected at a particular transect for each measured flow event.

Figure 5.4-59 is a scatter plot of detected zinc concentrations in surface water by river mile (RM 2–16). The symbols and colors indicate the sample type—point vs. transect—and the general flow conditions of the sampling event—low flow, stormwater-influenced, or high flow.

5.4.15.1 Zinc Data

Peristaltic samples were collected and analyzed by USEPA Method 6020 for total and dissolved zinc during Rounds 2A and 3A. Dissolved zinc was detected in 73 of 174 (42 percent) of samples and 133 of 174 (76 percent) of total zinc samples during the Round 2A and 3A sampling events.

Detected total zinc concentrations in all surface water samples during the Round 2A and 3A sampling events ranged from 1.65 to 57.9 µg/L. The range of detected concentrations of dissolved zinc in all Round 2A and 3A samples was 0.9 to 41.9 µg/L.

5.4.15.2 Zinc Relationship to River Flow Conditions

With the exception of one sample (station W022 on 12/2/2004) with elevated total (57.9 µg/L) and dissolved (41.9 µg/L) zinc concentrations, detected zinc concentrations were within a narrow range regardless of flow. With the exclusion of the highest total result, detected concentrations of total zinc in low-flow samples ranged from 1.65 to 8.8 µg/L at station W004 (RM 3.7E). Comparable to low flow, in high-flow samples, total zinc concentrations ranged from 1.85 to 8.4 µg/L. In contrast, total zinc was not detected during stormwater-influenced sampling.

With the exception of the highest dissolved result for W022 on 12/2/2004, detected dissolved zinc concentrations ranged from 0.9 to 4.9 µg/L at station W018 (RM 8.3) in November 2004 in low-flow samples. Dissolved zinc was only detected in one high-flow sample at 2.5 µg/L at station W005 in January 2006. In stormwater-influenced samples dissolved zinc was detected in 5 of 39 samples (4.8 to 6.6 µg/L, station W034, NB).

Zinc concentrations in samples collected during low-flow conditions ranged as follows (the station listed is for the maximum):

- Total zinc, single point: 1.6 to 58 µg/L at station W022 (RM 9.7W)
- Dissolved zinc, single point: 0.9 to 42 µg/L at station W022 (RM 9.7W)
- Total zinc, transect: 2.1 to 6.1 µg/L at station W023-W (RM 11W
- Dissolved zinc, transect: 1.4 to 2.2 µg/L at station W023 (RM 11).

Zinc concentrations in samples collected during high-flow conditions ranged as follows (the station listed is for the maximum):

- Total zinc, single point: 3 to 8.4 µg/L at station W031 (NB, RM 6.1W)
- Dissolved zinc, single point: Not detected
- Total zinc, transect: 1.9 to 6.4 µg/L at stations W024 (RM 16) and W023 (RM 11)
- Dissolved Zinc, transect: Detected in only one sample; 2.5 µg/L at station W005 (RM 3.9).

Zinc concentrations in samples collected during stormwater-influenced conditions in November 2006 ranged as follows (the station listed is for the maximum):

- Total zinc, single point: Not detected
- Dissolved zinc, single point: 4.8 to 6.6 µg/L at station W034 (NS, RM 7.5W)
- Total zinc, transect: Not detected
- Dissolved zinc, transect: Detected in a single transect stormwater-influenced sample at 5.1 µg/L at station W025-M (RM 2).

5.4.15.3 Spatial Distribution of Zinc

All of the total and dissolved concentrations of zinc in surface water were substantially below the ODEQ human health value of 2,100 µg/L developed to be protective of drinking water and consumption of organisms. An MCL has not been established for zinc.

5.4.16 TBT in Surface Water

Data for TBT in surface water are summarized in Tables 5.4-6 through 5.4-11 Transect samples are summarized by flow event in Tables 5.4-6, 5.4-8, and 5.4-10. Single-point samples are summarized by flow event in Tables 5.4-7a-d, 5.4-9a-d, and 5.4-11a-d. All TBT surface water data are presented in Table 5.4-25 by sample event and sample location.

TBT concentrations in surface water collected from peristaltic pumps are presented in bar graphs by flow event and by river mile/channel position on Figures 5.4-60 and Figure 5.4-61, respectively.

Figure 5.4-62 is a line plot of transect TBT concentrations in surface water by river mile (RM 2–16). The data points presented in this figure are averages of all data points collected at a particular transect for each measured flow event.

Figure 5.4-63 is a scatter plot of detected TBT concentrations in surface water by river mile (RM 2–16). The symbols and colors indicate the sample type—point vs. transect—and the general flow conditions of the sampling event—low flow, stormwater-influenced, or high flow.

5.4.16.1 TBT Data

Peristaltic samples of surface water were collected and analyzed by the Krone Method (Krone et al. 1989) for TBT during Rounds 2A and 3A. TBT was detected in a 12 of 174 (7 percent) of all surface water samples collected during the Round 2A and 3A sampling events. Detected TBT concentrations in all surface water samples collected during the Round 2A and 3A sampling events ranged from 0.00095 to 0.011 µg/L.

5.4.16.2 TBT Relationship to River Flow Conditions

The small number of TBT detections in surface water samples was associated with a narrow range of detected concentrations regardless of flow. Detected concentrations of TBT in low-flow samples ranged from 9.5×10^{-4} to 0.0023 µg/L. During high-flow sampling events TBT was detected twice at the same station, W035 RM 8.5E, with concentrations of 0.0021 µg/L (NS) and 0.0035 µg/L (NB).

Forty stormwater-influenced samples were analyzed for TBT. TBT was detected in only four of these samples at concentrations ranging from 0.001 to 0.011 µg/L.

TBT concentrations in samples collected during low-flow conditions ranged as follows (the station listed is for the maximum):

- Single point: 9.5×10^{-4} to 0.0023 µg/L at station W004 (NB, RM 3.7E)
- Transect: Not detected.

TBT concentrations in samples collected during high-flow conditions ranged as follows (the station listed is for the maximum):

- Single point: 0.0021 to 0.0035 µg/L at station W035 (RM 8.5)
- Transect: Not detected.

TBT concentrations in samples collected during stormwater-influenced conditions ranged as follows (the station listed is for the maximum):

- Single point: 0.0013 to 0.0014 µg/L at W035 (NS, RM 8.5E)
- Transect: 0.001 to 0.011 µg/L at W024 (NB, RM 16).

5.4.16.3 Spatial Distribution of TBT

There is neither a DEQ human health nor an aquatic life criteria for TBT ion.

5.4.17 Site-Specific Evaluation of Hydrophobic Contaminants

For the purposes of this evaluation and presentation, hydrophobic contaminants are defined as those contaminants or groups of contaminants that are insoluble or minimally soluble in water and are, therefore, expected to bind strongly to sediments and suspended particulates. The subset of hydrophobic contaminants included in this evaluation are PCBs, dioxins and furans, DDT and related compounds (DDx), and PAHs.

5.4.17.1 Distribution between Total PCBs Dissolved and Particulate Fractions

The following subsections describe observed trends in dissolved and particulate total PCB congener concentration fractions by river mile, event type, and sample type in the Round 2A and 3A data set. The spatial distribution of dissolved and particulate PCBs concentrations and relationships to flow rate, TSS, and f_{oc} are described. PCB congeners were detected in all XAD filter and column samples collected during Round 2A and 3A sampling events.

5.4.17.1.1 Total PCBs Dissolved and Particulate Concentrations

Total PCBs concentrations as a function of flow rate are presented in Figure 5.4-64. Figures 5. 4-65, and 5.4-66 show the dissolved and particulate fractions of total PCBs plotted against flow rate. All of the particulate and dissolved samples with concentrations >0.001 µg/L were collected during low-flow conditions, as well as a single dissolved sample collected during the stormwater-influenced sampling event. For the particulate fraction, low-flow single-point samples span a greater concentration range (up to almost 0.01 µg/L) as compared to the remaining samples, which are typically less than 0.001 µg/L. For the dissolved fraction of total PCBs, low-flow and stormwater-influenced samples cover similar concentration ranges, while high-flow samples exhibit generally lower concentrations. Low-flow point samples collected at the upper end of the dissolved concentration range (>5.0×10^{-4} µg/L) tended to have a higher particulate component of the total concentration.

The high-flow samples (both point and transect) tend to exhibit lower dissolved concentrations relative to the stormwater-influenced flow and low-flow samples. This suggests a different character/source of PCB-contaminated sediment and/or suspended solids concentration and character during high-flow events.

The transect sample collected at RM 11 during the low-flow event in November 2004 exhibited a high particulate to dissolved concentration ratio. As noted previously in Section 5.4.4.2, during collection of this sample, the field crews observed runoff from a nearby storm drain, which may have contributed to this result.

5.4.17.1.2 Total PCBs Associations with Suspended Solids

Total PCBs concentrations as a function of TSS are presented on Figure 5.4-67. High-flow samples (single-point and transect) exhibited the widest range and highest concentrations of TSS, from approximately 10 to 60 mg/L, but the lowest PCBs concentrations. Conversely, the remaining samples exhibited a greater range in concentration over a small range in TSS—low-flow TSS concentrations were less than 10 mg/L and stormwater-influenced concentrations ranged from approximately 0 to 20 mg/L TSS. The high-flow samples also exhibited a lower dissolved:particulate concentration ratio relative to the stormwater-influenced and low-flow samples.

Particulate total PCBs concentrations and particulate organic carbon (POC) concentrations are compared on Figures 5.4-68a-b. The high-flow samples (single-point and transect) exhibited lower PCBs concentrations for the corresponding POC than other flow regimes. The low POC values are consistent with the lower f_{oc} associated with TSS observed in high-flow samples, as shown on Figure 5.4-67. This observation suggests the introduction of suspended particles with low organic carbon content during high-flow events. Further, the solids that become suspended in the water column during high-flow events may have a different character (low f_{oc} and low PCBs concentrations) than those introduced during low-flow or stormwater-influenced events.

5.4.17.2 Distribution between Total PCDD/Fs Dissolved and Particulate Fractions

The following subsections describe the observed trends in dissolved and particulate total PCDD/Fs fractions by river mile, event type, sample type, TSS, and f_{oc} of the TSS. This analysis was specific to total PCDD/Fs and, therefore, does not extend to individual dioxins and furans.

5.4.17.2.1 Total PCDD/Fs Dissolved and Particulate Concentrations

The dissolved and particulate fractions of total PCDD/Fs concentrations for each surface water sample are presented as histograms by flow event type on Figure 5.4-14 and by channel position on Figure 5.4-15. As expected for hydrophobic compounds, total PCDD/Fs tend to partition to the particulate fraction in surface water within the Study Area. The two highest concentrations measured at RM 6.7 and 11 during low-flow and stormwater-influenced conditions, respectively, exhibit high particulate to dissolved ratios (greater than an order of magnitude difference between the two phases). This partitioning is consistent for all the samples.

5.4.17.2.2 Total PCDD/Fs Associations with Suspended Solids

Total concentrations as a function of TSS are presented on Figure 5.4-69. Total PCDD/Fs concentrations in high-flow transect samples appear to exhibit a slightly increasing PCDD/Fs concentration trend with higher suspended solids. Concentrations in low-flow and stormwater-influenced samples appear to vary independently of suspended solids concentration. The transect and single-point samples collected during low-flow and stormwater-influenced events were characterized by TSS values less than those of the high-flow event (Figures 5.4-70).

Particulate total PCDD/Fs concentrations and POC concentrations are compared on Figure 5.4-70. Relative to other flow regimes, POC was relatively low in high flow samples (single point and transect). The stormwater-influenced samples tended to exhibit marginally higher POC. Solids that become suspended during stormwater-influenced events may have a unique character of high f_{oc} and varying loads of PCDD/Fs. Samples characterized by higher concentrations of total PCDD/Fs did not have corresponding high TSS concentrations. However, these high total PCDD/Fs concentration samples did exhibit a high particulate-phase PCDD/Fs concentration as a function of POC.

5.4.17.3 Distribution between Total DDx Dissolved and Particulate Fractions

The following subsections describe the observed trends in total DDx dissolved and particulate fractions by river mile, event type, sample type, TSS, and f_{oc} of the TSS.

5.4.17.3.1 Total DDx Dissolved and Particulate Concentrations

The distribution of total DDx by river mile is presented on histograms by flow event type on Figures 5.4-20 and histograms by channel position on Figures 5.4-21a-b. Three samples collected at RM 2 (station W025) during low-flow conditions exhibited higher dissolved to particulate ratios. This may be due to the lower suspended solids load in the downstream portion of the Study Area (at RM 2) rather than an actual shift in partitioning behavior. However, these higher dissolved:particulate ratios are not exclusive to these samples.

Total DDx concentrations as a function of flow rate are presented in Figures 5.4-71a-b. With the exception of the highest total DDx concentrations that were measured at

RM 6.9 and 7.2, a relationship between flow rate and total DDx concentrations is not evident during low-flow conditions (Figure 5.4-71a). Considering the uncertainty associated with the discharge measurements noted in Section 5.4-2, the similarity in concentration for low flow events is not surprising. However, it is apparent in Figure 5.4-71b that there is a general increase in concentration with flow.

5.4.17.3.2 Total DDx Associations with Suspended Solids

Total concentrations as a function of TSS are presented on Figures 5.4-72a-b. The highest ratios of total DDx to TSS were exhibited in low-flow samples, while high-flow samples exhibited a much lower ratio of total DDx concentration to TSS. The low-flow and stormwater-influenced samples had low suspended solids loads (25 mg/L or lower) compared to high-flow samples (up to 62 mg/L). When the single-point samples with elevated total DDx concentrations are excluded, DDx concentrations tend to increase with TSS.

Particulate total DDx concentrations and POC concentrations are compared on Figures 5.4-73a-b. With the exception of low-flow single-point samples, total DDx concentrations appear independent of POC. High-flow samples exhibited higher TSS concentrations and lower f_{oc} on TSS percentages. Therefore, the higher concentrations in the surface water during high-flow events (Figures 5.4-72a-b) were present in spite of lower POC in the water column. Again, this may suggest a different source or sources of particles, upstream of the Study Area, given the high inflow concentrations at RM 16 and 11 during high-flow events. Higher POC concentrations were found in transect and single-point stormwater-influenced and low-flow samples with lower total particulate DDx concentrations.

5.4.17.4 Distribution between Total PAHs Dissolved and Particulate Fractions

The following subsections describe the observed trends in the dissolved and total PAHs fractions by river mile, event type, sample type, TSS, and f_{oc} of the TSS.

5.4.17.4.1 Total PAH s Dissolved and Particulate Concentrations

The spatial distribution of dissolved and particulate total PAHs concentrations is presented on histograms by flow event type and river mile on Figure 5.4-24 and by channel position on Figures 5.4-25a-b.

Total PAHs concentrations as a function of flow rate are presented in Figure 5.4-74. Four of the five highest concentrations of total PAHs were measured in single-point samples collected during low-flow conditions. Total PAHs concentrations tended to vary independently of flow condition. However, samples with elevated total PAHs concentrations were more evident in low-flow samples from RM 7 to 2 compared to the high-flow and stormwater-influenced sampling events. Downstream near RM 2, the low-flow sample concentrations were generally lower than those observed further upstream within the Study Area.

While a general trend of greater partitioning in the dissolved phased is evident, a notable exception was observed at station W035 at RM 8.5 during the January 2007 high-flow event. Both the NB and NS samples exhibited a greater particulate to dissolved concentration ratio. Also, at stations W011 (RM 6.3) and W005 (RM 4) the NB samples had noticeably higher particulate total PAHs concentrations in the low-flow and stormwater-influenced sampling events. In the January 2007 high-flow sampling event, this pattern was reversed at station W035 (RM 8.5), and the NS sample had the highest particulate total PAHs concentration.

5.4.17.4.2 PAHs Associations with Suspended Solids

Total PAHs concentrations as a function of TSS are presented on Figures 5.4-75. High-flow samples (single-point and transect) exhibited the widest range and highest concentrations of TSS but generally lower total PAHs concentrations. However, there does appear to be a trend of gradually increasing total PAHs concentrations with higher TSS values for the high-flow samples. Low-flow and stormwater-influenced samples tended to exhibit low TSS but a wider range of total PAHs concentrations.

Particulate total PAHs concentrations and POC concentrations are compared on Figure 5.4-76. The high-flow samples (single-point and transect) exhibited relatively low total PAHs concentrations and POC. The low POC values are consistent with the lower observed f_{oc} of the suspended solids during this flow condition. Several high-flow samples exhibited POC values equal to zero (Figure 5.4-76) because the calculated POC was considered to be zero if the DOC was greater than the TOC. These low POC values indicate that the high-flow events are associated with low f_{oc} sediments.

5.5 INDICATOR CONTAMINANTS IN TRANSITION ZONE WATER AND GROUNDWATER SEEPS

This section summarizes the Study Area data for TZW and groundwater seeps. As described in Section 3, the transition zone is defined as the interval where both groundwater and surface water comprise some percentage of the water occupying pore space in the sediments. The primary focus of the transition zone for this investigation is within the shallow sediment (0 to 38 cm bml), which includes the biologically active zone.[12] Deeper (>90 cm bml) TZW samples are also discussed here to lend insight into observed chemical distribution patterns.

The following subsections present tables, plan view maps with histograms, and scatter plots to support brief discussions of nature and extent for the select indicator contaminant list (Table 5.1-2). The full RI data sets for TZW and groundwater seeps for all sampled chemicals (those data of adequate quality) are presented in the RI SCRA database. Indicator contaminant data are summarized in Tables 5.5-1 and 5.5-2, and

[12] The biologically active zone is defined by the depth of biological processes. The depth of the true biologically active zone varies widely throughout the Study Area, based on factors that control benthic community structure, such as sediment texture, sediment-water interface dynamics, and organic loading.

data for the other contaminants are summarized in Appendix D4.1, Tables D4.1-1 and D4.1-2.

5.5.1 Transition Zone Water

The TZW sampling effort was not a harbor-wide study of TZW, but instead was a focused investigation offshore of nine study sites. Other areas of groundwater discharge to the river are not captured in this data set. Further, the sampling investigation of TZW did not seek to distinguish between areas impacted by upland sourced groundwater plumes and areas impacted by river sediments.[13] The approach to site selection is discussed in greater detail in Appendix C2.

The TZW investigations performed for the RI focused solely on areas of confirmed or likely groundwater plume discharge to the river and did not seek to characterize TZW pore water chemistry elsewhere in the Study Area. Accordingly, this discussion does not address TZW chemistry in areas with no upland groundwater discharge, or areas of clean groundwater flowing through contaminated sediments. Additionally, this study does not distinguish between the relative contribution of upland groundwater plumes and contaminants in sediment to the concentrations measured in TZW.

TZW data are presented on plan-view maps and/or scatter plots for select contaminants to support evaluation of sample composition. These presentations vary by analyte and the data are summarized in Table 5.5-1. As reflected in Table 5.5-1, the TZW analyte lists varied by study site; therefore, it was often unnecessary to produce maps for each river mile for a given analyte.

Maps: Map presentations of TZW data use color-coded symbols and fly out labels to provide the individual concentration values. This presentation includes distinction of peeper samples (0 to 38 cm bml), shallow TZW Trident samples (0 to 30 cm bml) and deeper Trident samples (90 to 150 cm bml), as well as non-LWG (0 to 90 cm bml) Geoprobe samples. Paired map sets are presented for each river mile to show filtered and unfiltered results, where available. Diffusion-based (peeper) samples are presented with a unique symbol on both filtered *and* unfiltered images to allow for a detailed evaluation of results. A histogram of detected contaminant concentrations is inset on each map to provide context for the results presented on the given river mile relative to the results from the entire Study Area. Histogram bins and concentration color ranges were selected based on professional judgment to best present the complete range of filtered and unfiltered concentration values observed across the Study Area. Maps 5.5-1 through 5.5-6 are provided for total DDx, total PAHs, arsenic, chromium, copper, and zinc.

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[13] In areas not directly affected by transport of contaminants originating in upland groundwater, contaminants may be present in TZW as a result of desorption from contaminated sediments and/or geochemical processes within the sediments and associated TZW.

Scatter Plots: Scatter-plot presentations of TZW data show sample concentrations plotted according to the river mile of the sample location. Color-coded symbols distinguish sample type and depth. Paired plot sets are presented for each contaminant to show filtered and unfiltered results, where available. Peeper samples are presented with a unique symbol on both filtered *and* unfiltered images to allow for a detailed evaluation of results. Scatter plots are provided for total DDx, total PAHs, arsenic, chromium, copper and zinc as Figures 5.5-1a-f.

5.5.1.1 TZW Data Set

The TZW presentation provided in this section supports the detailed site-by-site presentation and analysis of groundwater pathways provided in Appendix C2. The Appendix C2 presentation of TZW provides data analysis focused on identification of complete groundwater pathways from upland plumes to the transition zone, including some cross-media analysis. This section focuses on presentation of the distribution of indicator contaminants observed in the transition zone. As such, this section does not discuss all contaminants from groundwater sources within the Study Area or relate observations to sources. The TZW chemistry data used in this investigation were generated during the following field events:

- **2004 Pilot Study—**Integral (2005f [Appendix B])
- **2005 Round 2 GWPA—**Integral (2006f)
- **2005 Siltronic Investigation—**HAI (2005b); MFA (2005b)
- **2007 Gasco Investigation—**Anchor (2008d).

These sampling activities focused on the offshore area of nine sites along the west bank of the river (see Map 2.1-20):

- Kinder Morgan Linnton Terminal (RM 4.1 to 4.2)
- ARCO Terminal 22T (RM 4.7 to 4.9)
- ExxonMobil Oil Terminal (RM 4.8 to 5.1)
- Gasco (RM 6.1 to 6.5)
- Siltronic (RM 6.3 to 6.5)
- Rhone Poulenc (RM 6.7 to 6.9)
- Arkema (Acid Plant and Chlorate Plant areas; RM 7.2 to 7.5)
- Willbridge Terminal (RM 7.6 to 7.8)
- Gunderson (RM 8.3 to 8.5).

Two general types of sampling techniques were used to collect the TZW samples: diffusion samplers (small-volume peepers) and push probe samplers (Trident and Geoprobe tools were used as push probe samplers). These are described in detail in the Pilot Study FSP (Integral 2004c). All peeper samples were collected over the depth interval of 0 to 38 cm bml. Trident samples were collected at 30 cm bml, with a few deeper samples collected between 90 and 150 cm bml.[14] Geoprobe samples were collected at depths ranging from 30 to 6,300 cm bml, though only Geoprobe samples from 0 to 90 cm bml are presented in this discussion of TZW nature and extent.[15,16]

Because TZW samples were collected at a single point in time (for Trident and Geoprobe sampling) or over a 3-week equilibration period (for peeper sampling), LWG field sampling events were carefully timed to maximize the expected upland groundwater signal (i.e., the time of greatest groundwater discharge rate). For the Pilot Study and Round 2 TZW investigations, TZW analytical samples were collected from November 2004 to January 2005 and October to December 2005, respectively, before river water levels increased to the higher levels that typically occur from mid-winter through spring. The non-LWG TZW samples collected at Gasco that are included in this nature and extent discussion were collected between July and September 2007. The non-LWG TZW samples collected at Siltronic that are discussed here were collected in May and June of 2005.

5.5.1.2 Total PCBs

TZW samples collected from the offshore areas of the nine sites were not analyzed for PCBs.

5.5.1.3 Total PCDD/Fs

Samples were collected using Trident sampling methodology from two locations adjacent to Rhone Poulenc for PCDD/Fs analyses, RP03C and RP07B. Sample RP03C was collected from a depth of 30 cm bml and analyzed for filtered and unfiltered PCDD/Fs, which were not detected above laboratory reporting limits. A parent and duplicate sample were collected from RP07B from a depth of 30 cm bml for filtered and unfiltered PCDD/F analyses. Total PCDD/Fs were detected in the parent and duplicate unfiltered samples, with concentrations of 29 pg/L and 51.3 pg/L, respectively. Total PCDD/Fs were detected in the parent filtered sample, with a concentration of 0.865 pg/L. Due to the limited set of data, the observed distribution of total PCDD/Fs inTZW could not be adequately described; scatter plots and distribution maps are not presented.

[14] One Trident sample was collected at 60 cm bml at location CP-07-B. This sample is included with the 90 to 150 cm bml data set.

[15] Geoprobe data collected at 91 cm bml was collected for naphthalene and is included in Appendix D.

[16] For the Gasco study (sample IDs that begin with "GS-"), the sample collected at the uppermost depth in the 0 to 90 cm bml interval at each location is presented on maps to represent the TZW concentrations in the shallow layer. No deeper data collected as part of the Gasco study is presented. Only one sample (GS-C2, 73 to 103 cm bml) in the 2007 Gasco investigation was collected in the deeper (90 to 150 cm bml) sample interval; this sample is not included in this nature and extent discussion. For the Siltronic study (sample IDs that begin with "GP-"), samples collected at 31 cm bml are presented as shallow TZW.

5.5.1.4 TCDD TEQ

As described above, samples were collected using Trident sampling methodology from two locations adjacent to Rhone Poulenc for PCDD/Fs analysis, RP03C and RP07B. TCDD TEQs were calculated for the detected results in the parent and duplicate unfiltered samples collected from RP07B. The calculated concentrations were 1.72 J and 1.32 J pg/L, respectively. Due to the limited set of data, the observed distribution of TCDD TEQ in TZW could not be adequately described; scatter plots and distribution maps are not presented.

5.5.1.5 Total DDx

Total DDx was sampled offshore of the former Arkema Acid Plant and Rhone Poulenc sites. All but two of the sample locations were offshore of the Arkema Acid Plant site. As shown in Table 5.5-1, the following samples were collected:

- 8 peeper samples (0 to 38 cm bml), including two duplicates, collected offshore of the Arkema site
- 18 shallow (0 to 30 cm bml) Trident samples, including four duplicates, collected offshore of the Arkema site and Rhone Poulenc (with eight collocated filtered and unfiltered samples)
- 5 deep (90 to 150 cm bml) Trident samples (with collocated filtered and unfiltered samples collected at one location), including one location offshore of the Rhone Poulenc site.

DDx compounds were detected in two of the peeper samples, with concentrations of 0.032 J µg/L at AP03B-1 and 0.0135 J µg/L at AP04D. DDx compounds were detected in each of the shallow Trident unfiltered samples with concentrations ranging from 0.0075 J µg/L at AP04D to 3.05 J µg/L at AP03A. DDx compounds were detected in all but three of the shallow Trident filtered samples with detected concentrations ranging from 0.0084 NJA µg/L at AP03B-1 to 0.158 NJ µg/L at RP03C. DDx compounds were detected in all three of the deep Trident unfiltered samples collected offshore of the Arkema site (0.169 J to 5.73 J µg/L) and the one offshore of Rhone Poulenc (0.17 J µg/L). DDx compounds were also detected in the deep filtered sample collected offshore of Rhone Poulenc (0.179 J µg/L).

Map 5.5-1 presents filtered (top panel) and unfiltered (bottom panel) total DDx (constituent sums 2,4'- and 4,4'-DDD; 2,4'- and 4,4'-DDE; and 2,4'- and 4,4'-DDT are presented in Appendix D4.2)[17] concentrations measured in shallow (0 to 30 cm bml) Trident and deep (90 to 150 cm bml) Trident samples. Peeper samples (0 to 38 cm bml) are presented with a unique symbol on both filtered *and* unfiltered images to allow for a

[17] Note that 2,4'-DDD, 2,4'-DDE, and 2,4'-DDT were not sampled during the 2004 Pilot Study; therefore, the total DDx sum for these samples consists of only the 4,4'-DDx isomers. These results are distinguished with an "A" descriptor on Maps D4.2-1a-c.

detailed evaluation of results. Inset histograms on Map 5.5-1 show the distribution of total DDx sample concentrations for detected filtered, unfiltered, and peeper results. Scatter plots of filtered and unfiltered total DDx TZW concentrations from Trident and peeper samples are provided on Figure 5.5-1a. All sample results for summed and individual DDx isomers in TZW are presented in the SCRA database.

5.5.1.6 Total PAHs

Total PAHs were sampled at six of the nine TZW study sites: Kinder Morgan, ARCO, ExxonMobil, Gasco, Siltronic, and Willbridge Terminal. The discussion below focuses on total PAH results, which are summarized in Table 5.5-1. High molecular weight PAHs (HPAHs), low molecular weight PAHs (LPAHs), cPAHs, as well as individual PAH results, are presented in Appendix D4.1, Table D4.1-1.

Total PAHs data include the following samples:

- 24 peeper samples (0 to 38 cm bml), including 6 duplicates
- 81 shallow (0 to 30 cm bml) Trident samples, including 15 duplicates, collected from 35 locations (with collocated filtered and unfiltered samples collected at 31 locations)
- 14 deep (90 to 150 cm bml) Trident samples in this data set (with collocated filtered and unfiltered samples collected at 4 locations); duplicate samples collected at 2 locations
- 35 unfiltered samples collected with a Geoprobe from depths of 0 to 90 cm bml.

PAHs were detected in TZW samples offshore of all six sites. Total PAHs were identified in all of the peeper samples, with concentrations ranging from 0.105 J µg/L at KM10A, offshore of Kinder Morgan, to 300 J µg/L at GS01B, offshore of Gasco. Total PAHs were detected in all but three of the shallow Trident unfiltered samples, with concentrations ranging from 0.0025 J µg/L at EM02A, offshore of ExxonMobil, to 3,490 µg/L at GS07B, offshore of Gasco. Total PAHs were identified in all but two of the shallow Trident filtered samples, with detected concentrations ranging from 0.0031 J µg/L at W09A to 1,200 J µg/L at GS02A, which are offshore of Willbridge Terminal and Gasco, respectively.

For the deep Trident samples, total PAHs were detected in all seven unfiltered samples, with the minimum concentration of 0.61 J µg/L measured offshore of ARCO at R2AR02, and the maximum concentration of 430 µg/L measured offshore of Gasco at GS08D. Total PAHs were detected in all four Trident filtered deep samples, with concentrations ranging from 0.182 µg/L to 15.8 µg/L. The minimum filtered concentration was collocated with the minimum unfiltered deep measurement, at R2AR02. The maximum filtered deep concentration was measured at EM03A, offshore of ExxonMobil. Total PAHs were detected in all 35 Geoprobe samples collected from 0 to 90 cm bml, with a minimum concentration of 0.093 µg/L measured at GS-D3 offshore of Gasco, and a maximum concentration of 15,100 µg/L measured at GP73 offshore of the Gasco/Siltronic property boundary.

The total PAHs sample results are presented on Maps 5.5-2a–e. The map set presents filtered (top panel) and unfiltered (bottom panel) TZW results, where available, with inset histograms summarizing the distribution of samples shown on each map relative to the distribution across the TZW data set. Sample results collected between RM 6 and 7 are presented on two maps to allow for presentation of all sample concentration results in this densely sampled area (the first map shows concentration labels for LWG-collected data, and the second map shows concentration labels for non-LWG collected data). Observed total PAHs concentration ranges varied among the offshore study areas, with the highest total PAHs concentrations consistently being observed offshore of the Gasco and Siltronic sites. The lowest range of TZW total PAHs concentrations was observed offshore of the Willbridge Terminal site. These relative concentration ranges are apparent on the inset histograms on Maps 5.5-2a–e.

Scatter plots of filtered and unfiltered total PAHs TZW concentrations from Trident, peeper, and Geoprobe samples are provided on Figure 5.5-1b. These figures show sample concentrations along an x-axis noting the river mile of each sample location. Color-coded symbols distinguish sample type and depth. Paired plot sets are presented for each chemical to show filtered and unfiltered results, where available.

5.5.1.7 BEHP

TZW samples collected from the offshore areas of the nine study sites were not analyzed for BEHP.

5.5.1.8 Total Chlordanes

TZW samples collected from the offshore areas of the nine study were not analyzed for chlordanes.

5.5.1.9 Aldrin

TZW samples collected from the offshore areas of the nine study sites were not analyzed for aldrin.

5.5.1.10 Dieldrin

TZW samples collected from the offshore areas of the nine study sites were not analyzed for dieldrin.

5.5.1.11 Arsenic

TZW samples were analyzed for arsenic at all nine TZW study sites. Sampling results for arsenic are presented on scatter plots in Figure 5.5-1c. This figure shows sample concentrations along an x-axis noting the river mile of each sample location. Color-coded symbols distinguish sample type and depth. Paired plot sets are presented for each chemical to show filtered and unfiltered results, where available. Additionally, arsenic results are presented on Maps 5.5-3a–e. The map set presents filtered (top panel) and unfiltered (bottom panel) TZW results, where available, with inset histograms summarizing the distribution of samples shown on each map relative to the distribution across the TZW data set.

As shown in Table 5.5-1, arsenic data collected for TZW include results from the following samples:

- 39 peeper samples (0 to 38 cm bml), including 10 duplicates
- 60 shallow (0 to 30 cm bml) filtered Trident samples, including 11 duplicates
- 64 shallow (0 to 30 cm bml) unfiltered Trident samples, including 11 duplicates
- 24 unfiltered and 12 filtered deep (90 to 150 cm bml) Trident samples, including 5 duplicates
- 35 unfiltered and 4 filtered samples collected with a Geoprobe from depths of 0 to 90 cm bml.

Arsenic was detected in TZW samples offshore of all nine sites. Arsenic was detected in all but two of the peeper samples, with concentrations ranging from 0.3 J µg/L (locations ARC03B, ARC06B-1, and ARC06B-2) to 17.2 µg/L at W04C. The maximum detected concentration was identified offshore of the Willbridge Terminal site. Arsenic was detected in 55 of the shallow Trident filtered samples, with detected concentrations ranging from 0.55 µg/L at W09A, offshore of Willbridge Terminal, to 76.8 µg/L at EM03A, offshore of ExxonMobil. Arsenic was detected in all but three of the shallow Trident unfiltered samples with concentrations ranging from 0.72 µg/L at CP08B to 51.2 µg/L at W12A, which are offshore of Arkema and Willbridge Terminal, respectively.

For the unfiltered deep Trident samples, total arsenic was detected in all but one sample. The minimum detected concentration of 1.36 J µg/L was measured offshore of Gunderson at GN05A, and the maximum concentration of 77.1 µg/L was measured offshore of ExxonMobil at EM03A. Dissolved arsenic was detected in all 12 filtered deep Trident samples, with concentrations ranging from 0.98 to 77.3 µg/L. The minimum and maximum filtered concentrations were collocated with the minimum and maximum unfiltered concentrations, at stations GN05A and EM03A, respectively. Arsenic was detected in 22 of the 35 unfiltered Geoprobe samples, with the minimum detected concentration of 0.77 µg/L measured at GS-C3, and the maximum concentration of 65.4 J µg/L measured at GS-D3, both offshore of Gasco. Dissolved arsenic concentrations in the four filtered Geoprobe samples ranged from 0.94 to 5.52 µg/L, measured offshore of Gasco at stations GS-B1 and GS-B5, respectively.

5.5.1.12 Chromium

Samples collected at all nine TZW study sites were analyzed for chromium. Analytical results for chromium are presented on scatter plots in Figure 5.5-1d. These figures show sample concentrations along an x-axis noting the river mile of each sample location. Color-coded symbols distinguish sample type and depth. Paired plot sets are presented for each chemical to show filtered and unfiltered results, where available. Additionally, chromium results are presented on Maps 5.5-4a–e. The map set presents filtered (top panel) and unfiltered (bottom panel) TZW results, where available, with inset histograms summarizing the distribution of samples shown on each map relative to the distribution across the TZW data set.

As shown in Table 5.5-1, chromium data collected within the Study Area offshore of the nine sites referenced above include results from the following samples:

- 39 peeper samples (0 to 38 cm bml), including 10 duplicates
- 62 shallow (0 to 30 cm bml) filtered Trident samples, including 11 duplicates
- 65 shallow (0 to 30 cm bml) unfiltered Trident samples, including 11 duplicates
- 25 unfiltered and 13 filtered deep (60 to 150 cm bml) Trident samples, including 3 unfiltered and 2 filtered duplicates
- 35 unfiltered and 4 filtered samples collected with a Geoprobe from depths of 0 to 90 cm bml.

Chromium was detected in TZW samples collected from locations offshore of all nine sites. Chromium was detected in 17 of the Peeper samples, with concentrations ranging from 0.92 µg/L at location CP09D to 31.6 µg/L at CP07B, both of which were identified offshore of the Arkema site. Chromium was detected in 34 of the shallow Trident filtered samples, with detected concentrations ranging from 0.2 J µg/L at W09A, offshore of Willbridge Terminal, to 98.3 µg/L at CP07B, offshore of Arkema. Chromium was detected in 45 of the shallow Trident unfiltered samples with concentrations ranging from 0.79 µg/L at SL03A to 122 µg/L at CP07B, which are offshore of Siltronic and Arkema, respectively.

For the unfiltered deep Trident samples, total chromium was detected 20 samples. The minimum detected concentration of 0.8 µg/L was measured adjacent to Rhone Poulenc at RP02E, and the maximum concentration of 102 µg/L was measured offshore of the Arkema site at CP07B. Dissolved chromium was detected in seven filtered deep Trident samples, with concentrations ranging from 0.36 µg/L at EM01A, offshore of ExxonMobil, to 49.6 µg/L at CP07B. Chromium was detected in all of the 35 unfiltered Geoprobe samples, with the minimum detected concentration of 2.07 µg/L measured at GS-D2 offshore of Gasco, and the maximum concentration of 537 µg/L measured at GS-B9 offshore of Siltronic. Dissolved chromium concentrations in the three detected filtered Geoprobe samples ranged from 0.45 to 0.69 µg/L, measured offshore of Gasco at stations GS-B4 and GS-B5, respectively.

5.5.1.13 Copper

Samples collected at all nine TZW study sites and non-LWG Gasco and Siltronic field events were analyzed for copper. Analytical results for copper are presented on scatter plots in Figure 5.5-1e. These figures show sample concentrations along an x-axis noting the river mile of each sample location. Color-coded symbols distinguish sample type and depth. Paired plot sets are presented for each chemical to show filtered and unfiltered results, where available. Additionally, copper results are presented on Maps 5.5-5a–e. The map set presents filtered (top panel) and unfiltered (bottom panel) TZW results, where available, with inset histograms summarizing the distribution of samples shown on each map relative to the distribution across the TZW data set.

As shown in Table 5.5-1, copper data collected within the Study Area offshore of the nine sites referenced above include results from the following samples:

- 39 peeper samples (0 to 38 cm bml), including 10 duplicates
- 50 shallow (0 to 30 cm bml) filtered Trident samples, including 9 duplicates
- 53 shallow (0 to 30 cm bml) unfiltered Trident samples, including 9 duplicates
- 18 unfiltered and 12 filtered deep (90 to 150 cm bml) Trident samples, including 3 unfiltered and 2 filtered duplicates
- 35 unfiltered and 4 filtered samples collected with a Geoprobe from depths of 0 to 90 cm bml.

Copper was detected in TZW samples collected from locations offshore of all nine sites. Copper was detected in five peeper samples, with concentrations ranging from 1.63 µg/L at location ARC02B to 22.1 µg/L at CP07D. The maximum detected concentration was identified offshore of the Arkema site. The remaining four detected copper concentrations were identified in samples collected from locations offshore of ARCO.

Copper was detected in 10 of the shallow Trident filtered samples, with detected concentrations ranging from 0.36 µg/L at R2KM01 to 3.63 µg/L at R2RP03, which are offshore of Kinder Morgan and Rhone Poulenc, respectively. Copper was detected in 35 of the shallow Trident unfiltered samples with concentrations ranging from 1.54 µg/L at ARC02B to 63.1 µg/L at EM02C, which are offshore of ARCO and ExxonMobil, respectively.

For the unfiltered deep Trident samples, total copper was detected 13 samples. The minimum detected concentration of 1.79 µg/L was measured adjacent to Rhone Poulenc at RP02E, and the maximum concentration of 43.7 µg/L was measured offshore of the Siltronic site at SL03F. Dissolved copper was detected in 7 filtered deep Trident samples, with concentrations ranging from 0.24 µg/L at GN05A, offshore of Gunderson, to 1.89 J µg/L at R2AR02, offshore of ARCO. Copper was detected in 29 of the unfiltered Geoprobe samples, with the minimum detected concentration of 1.01 J µg/L measured at GS-C6, offshore of Gasco, and the maximum concentration of 555 µg/L measured at GS-B9, offshore of Siltronic. Dissolved copper concentrations were detected in all four filtered Geoprobe samples; concentrations ranged from 0.28 µg/L at locations GS-B4 and GS-B5 to 0.79 µg/L at GS-B2, all measured offshore of Gasco.

5.5.1.14 Zinc

Samples collected from all nine TZW study sites and non-LWG Gasco and Siltronic field events were analyzed for zinc. Analytical results for zinc are presented on scatter plots in Figure 5.5-1f. These figures show sample concentrations along an x-axis noting the river mile of each sample location. Color-coded symbols distinguish sample type and depth. Paired plot sets are presented for each chemical to show filtered and unfiltered results, where available. Additionally, zinc results are presented on Maps 5.5-6a–e. The map set presents filtered (top panel) and unfiltered (bottom panel) TZW results, where available, with inset histograms summarizing the distribution of samples shown on each map relative to the distribution across the TZW data set.

As shown in Table 5.5-1, zinc data collected within the Study Area offshore of the nine sites referenced above include results from the following samples:

- 39 peeper samples (0 to 38 cm bml), including 10 duplicates
- 60 shallow (0 to 30 cm bml) filtered Trident samples, including 11 duplicates
- 64 shallow (0 to 30 cm bml) unfiltered Trident samples, including 11 duplicates
- 24 unfiltered and 12 filtered deep (60 to 150 cm bml) Trident samples, including 3 unfiltered and 2 filtered duplicate samples
- 35 unfiltered and 4 filtered samples collected with a Geoprobe from depths of 0 to 90 cm bml.

Zinc was detected in TZW samples collected from locations offshore of all nine sites. Zinc was detected in 18 peeper samples, with concentrations ranging from 7.11 J µg/L at location R2KM02, which is offshore of Kinder Morgan, to 418 µg/L at R2CP01. The maximum detected concentration was identified offshore of the Arkema site.

Zinc was detected in 32 of the shallow Trident filtered samples, with detected concentrations ranging from 0.95 µg/L at R2KM01 to 526 µg/L at R2AR01, which are offshore of Kinder Morgan and ARCO, respectively. Zinc was detected in 39 of the shallow Trident unfiltered samples with concentrations ranging from 7.81 J µg/L at W09A to 556 µg/L at R2AR01, which are offshore of Willbridge Terminal and ARCO, respectively.

For the unfiltered deep Trident samples, total zinc was detected 17 samples. The minimum detected concentration of 18.6 J µg/L was measured at AP03D offshore of Arkema Acid Plant area, and the maximum concentration of 161 µg/L was measured at CP07B offshore of the Arkema Chlorate Plant area. Dissolved zinc was detected in seven filtered deep Trident samples, with concentrations ranging from 1.87 J µg/L at AR01A to 9.78 µg/L at R2AR02, both offshore of ARCO. Zinc was detected in all but one of the 35 unfiltered Geoprobe samples, with the minimum detected concentration of 8.3 µg/L measured at GS-C6 and the maximum concentration of 3,590 µg/L measured at GS-B4, both offshore of Gasco. Dissolved zinc concentrations in the filtered

Geoprobe samples ranged from 2.93 to 22.5 µg/L, measured offshore of Gasco at stations GS-B2 and GS-B5, respectively.

5.5.1.15 TBT

TZW samples collected from the offshore areas of the nine study sites were not analyzed for TBT.

5.5.2 Groundwater Seeps

This section summarizes the location, available chemical data, and data quality assessment for upland groundwater seeps. The groundwater seep data set is limited because a comprehensive seep characterization was not part of the Portland Harbor RI program. Consequently, the data set does not lend itself to the same contaminant distribution discussions applied to TZW and other media in this report (specifically, discussion of select analytes).

5.5.2.1 Groundwater Seep Locations

A seep reconnaissance survey was conducted during Round 1 of the Portland Harbor RI/FS (GSI 2003a) to support the BHHRA and development of the CSM. This survey documented readily identifiable groundwater seeps based on visual observations along approximately 17 miles of riverbank from RM 2 to 10.5. For the purposes of this survey, a seep was defined as groundwater discharge above the Willamette River waterline as observed during the seep reconnaissance survey. This groundwater may be discharged from local shallow groundwater systems, perched groundwater, water seeping through utility backfill, or return flow from tidally influenced bank storage. Observed seeps were classified into one or more of five types:

- Seepage line at the base of embankments (nine seeps)
- Linear and point seeps at the foot of beaches (six seeps)
- Seepage through backfill surrounding outfalls (four seeps)
- Seepage of NAPL (two seeps)
- Potential seep locations identified by observation of extensive ferric hydroxide staining of bank materials (eight potential seeps).

Additionally, eight seeps were categorized as combinations of the above seep types.

5.5.2.2 Groundwater Seep Water Quality Data

Seep water quality samples have been collected at six seeps in four general areas (Map 5.4-7). The water quality sampling efforts conducted for upland groundwater seeps include:

- City of Portland stormwater Outfalls 22B and 22C, located directly north and south of the Railroad Bridge at RM 6.89 and 6.82, respectively, are type 3 (backfill surrounding outfalls) seeps. Both Rhone Poulenc and NW Natural have collected water quality samples in Outfalls 22B and 22C to evaluate potential groundwater infiltration to the conveyance systems. These results are described in the next two bullets in this list.

- Rhone Poulenc sampled Outfall 22B on five occasions between October 1, 1993 and September 23, 2004, and Outfall 22C four times between August 13, 2002 and September 23, 2004. Samples were collected at the end of the pipe and were analyzed for 231 individual parameters, including conventionals, total PCDD/Fs, herbicides, metals, total PAHs, PCB Aroclors, pesticides, petroleum hydrocarbons, phenols, phthalates, SVOCs, and VOCs. The results are Category 1 data validated to the QA2 level, with the exception of petroleum hydrocarbon results measured on September 23, 2004, which are Category 2 data and will be excluded from this discussion.
- NW Natural sampled Outfall 22C on February 24, 2005 for 89 individual parameters, including conventionals, metals, total PAHs, phenols, phthalates, SVOCs, and VOCs. Data were validated to Category 2, QA1 level.
- Seeps-01, -02, and -03 are located at the Gunderson site near RM 8.5. These type 3 seeps are associated with cracked stormwater drain pipes. Each seep was sampled once in November 2004 and again in April 2005, with samples analyzed for 31 individual parameters, including conventionals, metals, PCB Aroclors, PAHs, petroleum hydrocarbons, SVOCs, VOCs, and phthalates. Data were validated to Category 1, QA1.
- ExxonMobil sampled areas with visible sheen on sand and in pooled water along the riverbank at the ExxonMobil site under the direction of DEQ on August 13, 2004 (Kleinfelder 2004a) and October 6, 2003. Two composite samples were analyzed as soils for total petroleum hydrocarbons (diesel), total petroleum hydrocarbons (gasoline), and total petroleum hydrocarbons (residual). Data were validated to the QA1 level. All results were below instrument detection limits.

A summary of the indicator contaminant data collected at each of the above mentioned locations is provided in Table 5.5-2. Seep data collected from these locations for other contaminants are presented in Appendix D4.1 (Table D4.1-2).

5.6 INDICATOR CONTAMINANTS IN BIOTA

This section summarizes the fish and invertebrate tissue data collected in support of the RI. Fish and invertebrate tissue chemistry data were collected to estimate exposure concentrations (as tissue residues or diet) for each of the targeted species, which were selected to represent a variety of feeding guilds. The discussion of the indicator contaminants addressed in this section focuses primarily on the following elements:

- A description of the data set for each indicator contaminant, including the number of samples collected of each fish and invertebrate species by tissue type and the locations from which those samples were collected

- A summary of the range of detected indicator contaminant concentrations in the tissue samples collected of each species from locations in the Study Area, as well as in samples collected from the Downstream Reach, the Study Area, the Downtown Reach and from the Upriver Reach including locations above Willamette Falls
- A presentation of the locations with the highest indicator contaminant concentrations found in the Study Area, as well as in samples collected from the other reaches listed in previous bullet.

The following subsections include presentation of tables and other graphical formats to support brief discussions of the nature and extent of contamination in biota tissue associated with the selected indicator contaminants (Table 5.1-2). Table 5.6-1 provides a summary of data for fish tissue collected from the Study Area (RM 1.9–11.8). Table 5.6-2 provides a summary of data for fish tissue collected from the Downstream Reach (RM 0–1.9 and Multnomah Channel). Table 5.6-3 provides a list of the fish and invertebrate samples collected from the Downtown Reach (RM 11.8–15.3), and from the Upriver Reach (RM 15.3–28.4), including locations above Willamette Falls. Table 5.6-4 provides a summary of data for fish tissue collected from the Downtown and Upriver Reaches. Table 5.6-5 provides a summary of data for invertebrate tissue collected from the Study Area. Table 5.6-6 provides a summary of data for invertebrate tissue collected from the Downstream Reach. Table 5.6-7 provides a summary of data for invertebrate tissue collected from the Downtown Reach and the Upriver Reach. The full RI data sets for biota samples for all analyzed contaminants (those data of adequate quality) are presented in the RI SCRA database and summarized in Appendix D5.

All contaminant concentrations in tissue are reported on a wet-weight basis. Summary statistics for indicator contaminants in fish and invertebrate tissue samples are provided in Tables 5.6-1, 5.6-2, and 5.6-4 through 5.6-7. Two sets of summary information are provided in the summary statistics tables:

- Detected concentrations only
- Detected and non-detected concentrations combined.

The nature and extent of indicator contaminants in fish and invertebrate tissue provided in this section is based on the data and statistics calculated for detected concentrations only. Summary statistics for all analytes measured in tissue samples are provided in Tables D5.1-1 through D5.1-6 in Appendix D5. Indicator contaminant data are presented for the Study Area, Downstream Reach and Downtown Reach, followed by a presentation of the Upriver Reach including above the Willamette Falls areas. Data are not available for every indicator contaminant in every tissue since study designs varied and insufficient material was available in some cases to complete all planned analyses. Tables 2.3-8 and 2.3-9a-b summarize the samples and analyses available for the Study Area as provided in the SCRA database. The discussion of the indicator contaminants includes a description of the data set, concentration ranges, and references to figures and tables to help interpret the distribution of indicator contaminants in biological tissues.

The biota data are depicted in several graphical formats: scatter plots, box-whisker plots, and concentration maps. Because the number of tissue samples collected from areas immediately adjacent to the Study Area (i.e., Downstream Reach and Downtown Reach) was small, these biota data are combined with the Study Area data set in the graphical displays. However, the discussion of the nature and extent of indicator contaminants, presented below per each individual indicator contaminant, and the associated tables, provide a summary of the data by species (e.g., clam) and tissue type (e.g., whole body fish or depurated clam tissue without shell) for samples collected from the Downstream Reach, within the Study Area, from the Downtown Reach, and from the Upriver Reach. Thus, the data from the referenced composite samples in Table 5.6-8, which are here combined for presentation purposes only, are not part of the Study Area data set and were not included in the Study Area BHHRA (Appendix F) and BERA (Appendix G) data sets.

Scatter Plots: A series of scatter plots (Figures 5.6-1 through 5.6-14) for each indicator contaminant provides contaminant concentrations by river mile for select species (smallmouth bass, sculpin, clam, crayfish, and *Lumbriculus variegatus* worms) and tissue type (e.g., whole body fish, depurated clam tissue without shell). A number of species were caught within target fishing zones (1-mile fishing zones; 3-mile fishing zones; and 3-mile fishing zones for Round 1 and 4-mile fishing zones for Round 3 for carp specifically). Individual fish caught in different locations within each fishing zone were composited to create a sample for analysis. The centroid of each fishing zone is used to represent these composite samples on the scatter plots.

Box-Whisker Plots: Figures 5.6-15 through 5.6-28 are a series of box-whisker plots that present the concentrations of indicator contaminants for whole body tissue samples of the various fish and invertebrate species. These plots were developed using R for Windows v. 2.7.0. (R Development Core Team 2008). The horizontal center line in each box represents the median concentration, and the top and bottom of the box represent the upper and lower quartiles, respectively. The upper whisker represents the highest concentration that is less than the upper quartile plus 1.5 times the interquartile range, and the lower whisker represents the lowest concentration that is greater than the lower quartile minus 1.5 times the interquartile range. Outliers are represented individually by small circles above and below the boxes.

Box-whisker plots and scatter plots for additional contaminants identified in Table 5.1-2 are provided as part of Appendix D5.

Concentration Maps: Concentration maps (Maps 5.6-1 through 5.6-16) plot indicator contaminant concentrations (and qualifiers) for each tissue sample used in the BHHRA or BERA. All forms of tissue (i.e., whole body, fillet, fillet without skin, stomach contents, etc.) are shown. Individual fish collection locations from each sample composite are color coded to match the appropriate sample composite identification code from the concentration table. Units are indicated for each contaminant in the individual sample concentration tables. The summary of indicator contaminant concentrations presented below for each species and tissue type includes a parenthetical reference to the river mile and associated map for the maximum detected concentration.

5.6.1 Biota Data Set

The biota data set includes fish and invertebrate samples collected by the LWG as part of Rounds 1, 2, and 3 of the Portland Harbor RI/FS, as well as samples collected by other parties, as described in Section 2. The number and type of tissues collected from the Study Area are provided in Section 2 of this RI. Table 2.3-8 provides the study name, sample count, and a summary of analyses for each species and tissue type, and Tables 2.3-9a-b detail the sample count for each individual contaminant analyzed for each species and tissue type for LWG and non-LWG samples. Table 2.3-10 provides the number of fish and invertebrates in each sample composite.

Eleven fish species, four benthic invertebrate species, epibenthic communities, and fish stomach contents are represented. Fish and invertebrate tissue samples were collected from the Study Area and from adjacent areas, including the Downstream Reach and Multnomah Channel near its divergence from the lower Willamette River and the Downtown Reach. Biota data were also available from samples collected at locations within the Upriver Reach (RM 15.3–28.4) of the river.

5.6.2 Total PCBs in Biota

PCBs in tissue samples were analyzed as Aroclors or congeners. In most Round 1 samples, both analyses were completed; however, Round 1 whole-body largescale sucker, northern pikeminnow, peamouth, all fillets, and crayfish samples were only analyzed for Aroclors. In Rounds 2 and 3, LWG biota samples were analyzed for all 209 PCB congeners. Biota samples collected by other parties were sometimes analyzed for a limited number of congeners. In accordance with the RI data summation rules, samples with fewer than 100 PCB congeners were not summed. This section presents a summary of the distribution of total PCBs using total congeners, when available. When congener data are unavailable, total PCBs concentrations are based on total Aroclors for each species and tissue type. Scatter plots showing the distribution of total PCBs concentrations in select biota tissue collected from the Study Area are provided on Figures 5.6-1a-e. A box-whisker plot showing the distribution of PCB concentrations in whole body tissue samples collected of each species is provided on Figure 5.6-15.

5.6.2.1 PCBs in Fish Tissue

This section presents a summary of the distribution of total PCBs in fish tissue by presenting total PCBs concentrations. As shown in Table 5.6-1, PCBs were detected in all fish samples collected from the Study Area. Additional sculpin samples were collected from the Downstream Reach, as presented in Table 5.6-2. Selected fish species were also collected from the Downtown Reach, as shown in Table 5.6-4. Species-specific data are summarized below by tissue type.

Black Crappie

Individual black crappie samples were collected over a 6-mile reach of the river and were composited for laboratory analysis. A total of four fillet (with skin) composite samples collected within the Study Area were submitted for laboratory analysis of PCB Aroclors, and presented as total PCBs in Table 5.6-1. PCB Aroclors were detected in all four fillet samples, with concentrations ranging from 19.6 to 32 µg/kg (maximum concentration between RM 6 and 9; Map 5.6-1b).

A total of four whole body composite samples collected from the Study Area were analyzed for 209 PCB congeners and Aroclors. Total PCB congeners were detected in all samples, ranging from 103 J to 301 J µg/kg (maximum concentration between RM 6 and 9; Map 5.6-1b).

Brown Bullhead

Brown bullhead samples were collected over an approximately 6-mile reach of the river and were composited for laboratory analysis. A total of six skin-off fillet composite samples collected within the Study Area were submitted for laboratory analyses of PCB Aroclors, which are also presented as total PCBs in Table 5.6-1. PCB Aroclors were detected in all samples, with concentrations ranging from 37 to 1,300 J µg/kg (maximum concentration between RM 6 and 9; Map 5.6-2b).

A total of six whole body composite samples collected within the Study Area were submitted for laboratory analyses of PCBs. PCBs were detected in all six samples, with total PCBs based on congener analysis ranging from 83.3 J to 1,950 J µg/kg (maximum concentration between RM 6 and 9; Map 5.6-2b).

Two whole body brown bullhead were collected from the Upriver Reach, with total PCB congener concentrations ranging from 19.1 J to 56.3 J (maximum concentration between RM 23 and 24; Map 5.6-15a).

Carp

Twelve skin-on fillet composite samples of carp were collected within the Study Area and analyzed for PCB congeners. PCBs were detected in all 12 skin-on fillet composite samples, with concentrations ranging from 265 J to 19,700 J µg/kg (maximum concentration between RM 4 and 8; Map 5.6-3b).

Twelve whole body composite samples of carp were also collected within the Study Area and analyzed for PCBs. These 12 samples included 6 whole body samples and 6 samples based on combined fillet and body without fillet fractions. PCBs were detected in all 12 samples, with total PCB concentrations ranging from343 J to 25,100 J µg/kg (maximum concentration between RM 4 and 8; Map 5.6-3b). Six body without fillet samples were analyzed, and PCBs were detected all 6 samples, with total

PCB concentrations ranging from 405 J to 27,100 µg/kg, also collected between RM 4 and 8.

Nine composite carp samples were collected within the Downstream Reach (between RM 0 and 1.9 and Multnomah Channel; Map 5.6-3a) and submitted for analysis of PCBs, which were detected in each sample Total PCBs concentrations for three skin-on fillet composite samples ranged from 210 to 260 µg/kg. Total PCBs concentrations for three body without fillet composite samples ranged from 322 J to 417 J µg/kg. Total PCBs concentrations for three combined fillet and body without fillet fractions ranged from 295 J to 377 J µg/kg.

Chinook Salmon

Chinook salmon composite samples were collected within the Study Area and from the Downtown and Upriver Reaches. Fifteen juvenile whole body Chinook salmon samples were collected within the Study Area and were composited for laboratory analyses of PCBs. PCBs were detected in all 15 samples, with total PCB concentrations ranging from 30 J to 277 J µg/kg (maximum concentration between RM 3 and 4; Map 5.6-4a).

Eight juvenile whole body composite samples were also collected from the Upriver Reach, with concentrations of total PCBs ranging from 12.8 J to 21.6 J µg/kg (between RM 17 and 18; Map 5.6-16).

Also collected from the Clackamas River Fish Hatchery were three skin-on fillet samples, with total PCBs concentrations ranging from 8.71 to 15.3 µg/kg. Finally, three skin-off fillet samples were collected from the Upriver Reach, and total PCBs concentrations in those samples ranged from 6.89 to 12.4 µg/kg.

Five composites of juvenile Chinook salmon were collected within the Study Area and submitted for PCB analyses of stomach contents. PCBs were detected in all five samples, with total PCBs based on congener analysis ranging from 53.8 J to 162 J µg/kg (maximum concentration between RM 9 and 10; Map 5.6-4b).

Stomach contents of the single composite sample collected from the Upriver Reach contained 10.6 J µg/kg of total PCBs (between RM 17 and 18; Map 5.6-16).

Lamprey Ammocoetes and Macropthalmia

Six juvenile (ammocoetes and macropthalmia) lamprey composite samples were collected within the Study Area and were composited for PCB analyses. PCBs were detected in all six samples, with total PCBs concentrations ranging from 80.6 J to 399 J µg/kg (ammocoete; maximum concentration between RM 1.9 and 10; Map 5.6-8). PCBs were also detected in the eight composite samples collected from the Upriver Reach, and total PCBs in those composite samples ranged from 31.3 J to 52.8 J µg/kg (maximum concentration between RM 18 and RM 19; Map 5.6-16).

Largescale Sucker

Six whole body composites of largescale sucker were collected from the Study Area and submitted to the laboratory for PCB analysis. Total PCBs concentrations of these six samples ranged from 95 to 2,020 J µg/kg (maximum concentration between RM 2 and 4; Map 5.6-10a).

Northern Pikeminnow

Six whole body composites of northern pikeminnow were collected from the Study Area and submitted to the laboratory for PCB analysis. Total PCBs concentrations of these six samples ranged from 370 to 1,800 µg/kg (maximum concentration between RM 6 and 7; Map 5.6-10a).

Peamouth

Four whole body composites of peamouth were collected from the Study Area and submitted to the laboratory for PCB analysis. Total PCBs concentrations of these four samples ranged from 138 to 290 µg/kg (maximum concentration between RM 8 and 10; Map 5.6-10b).

Sculpin

Forty-two whole body composite samples of sculpin were collected and submitted to the laboratory for PCB analysis. Thirty-eight of these samples were collected from the Study Area, with total PCBs concentrations ranging from 62 J to 8,770 J µg/kg (RM 11 to 12; Map 5.6-11f).

Two whole body composites were collected below the Study Area, with total PCB concentrations of 80.9 J and 87.7 J µg/kg (maximum concentration between RM 1 and 2; Map 5.6-11a). Two whole body sculpin composites were also collected from the Downtown Reach, with total PCBs concentrations of 55.8 J and 277 J µg/kg (maximum concentration between RM 11 and 13; Map 5.6-11f).

Smallmouth Bass

Sixty-one smallmouth bass samples were collected and submitted to the laboratory for PCB analysis. All but 6 of these samples were collected from the Study Area. Study Area samples included 23 fillet composites and 14 whole body composites (Maps 5.6-12a-e). In addition, concentrations were derived for 18 composites by calculating concentrations for fillet and body without fillet fractions.

Total PCBs concentrations of these Study Area smallmouth bass samples ranged as follows:

- Fillet—27 J to 1,480 J µg/kg (RM 11 to RM 12; Map 5.6-12e)
- Combined fillet and body without fillet fractions—205 J to 6,600 J µg/kg (RM 11 to 12; Map 5.6-12e)
- Body without fillet—264 J to 8,160 J µg/kg (RM 11 to 12)

- Whole body—344 J to 4,530 J µg/kg (RM 8 to near 9)

Total PCB concentrations of the six whole body composites collected from the Downtown and Upriver Reaches ranged from 78.1 J to 317 J µg/kg ((maximum concentration between RM 20 and RM 25; Map 5.6-15a).

Sturgeon

Twenty-one sturgeon samples were collected from the Study Area and submitted to the laboratory for PCB analysis. These included 5 composite skin-off fillet samples, 15 whole body samples, and 1 sample for stomach contents.

Whole body total PCB concentrations ranged from 69.1 J to 325 J µg/kg (maximum concentration between RM 7 and 8). Total PCB concentrations of skin-off fillet samples ranged from 84.7 to 964 µg/kg (maximum concentration between RM 6 and 7; Map 5.6-13b). The total PCB concentration of the single stomach contents sample equaled 10.6 J µg/kg (between RM 7 and 8; Map 5.6-13b).

5.6.2.2 PCBs in Invertebrate Tissue

This section presents a summary of the distribution of total PCBs concentrations in invertebrate tissue samples. As shown in Table 5.6-5, PCBs were detected in all invertebrate species collected from the Study Area, with the exception that PCBs were not detected in 15 out of 27 crayfish tissue composites that were only analyzed for Aroclors, which have a higher detection limit than PCB congeners. Aroclors were only measured in Round 1 and non-LWG samples. Additional invertebrate samples were collected from the Downstream Reach, as presented in Table 5.6-6. Selected invertebrate species were also collected from the Downtown Reach, as shown in Table 5.6-7. Species-specific data are summarized below by tissue type.

Clams (Resident)

All clam samples consisted of composited soft parts only (body without shell). Forty composites of resident clams (non-depurated) were collected within the Study Area and submitted to the laboratory for PCB analysis, with concentrations ranging from 50.1 J to 2,650 J µg/kg (maximum concentration between RM 6 and 7; Map 5.6-5d). Three additional depurated composite samples were collected within the Study Area, with total PCBs concentrations ranging from 82.6 J to 480 µg/kg (maximum concentration between RM 11 and 12; Map 5.6-5f).

Three composite clam samples, one depurated and two not depurated, were collected from the Downstream Reach. The total PCB concentrations in the non-depurated samples were 70.4 J and 127 µg/kg, while the total PCB concentration of the depurated sample was 110 J µg/kg (Map 5.6-5a). An additional non-depurated clam composite sample was collected in the Downstream Reach with a total PCBs concentration of 70.4 J µg/kg (Map 5.6-5a).

Three composite clam samples, one depurated and two not depurated, were also collected from the Downtown Reach. The total PCB concentrations in the two non-depurated clam samples were 39.1 J and 141 J µg/kg (Map 5.6-5f). The total PCBs concentration of the depurated sample from the Downtown Reach was 87.2 J µg/kg (Map 5.6-5f).

Clams (Laboratory-Exposed)

Thirty-four additional clam results were generated by exposing laboratory-reared clams to Study Area sediments, followed by analyses of soft body parts for PCBs. The total PCBs concentrations of these 34 laboratory-exposed samples ranged from 19.1 J to 189 µg/kg (maximum concentration between RM 8 and 9; Map 5.6-6e).

One clam result was generated by exposing laboratory reared clams to Downstream Reach sediments, followed by analyses of soft body parts for PCBs. The total PCB concentration of this one sample is 19.1 J µg/kg (Multnomah Channel; Map 5.6-6b).

Crayfish

Thirty-two whole body crayfish composites were collected within the Study Area and analyzed for PCBs. PCBs were not detected in 10 samples, but were detected in 22 samples. Total PCBs concentrations of those 22 samples ranged from 10.1 J to 1,190 J µg/kg (maximum concentration between RM 11 and 12; Map 5.6-7d).

Two composite whole body crayfish samples were collected from the Downstream Reach. The total PCBs concentrations in these two samples were 7.14 J and 7.16 J µg/kg (between RM 1 and 2; Map 5.6-7a).

Two composite whole body crayfish samples were also collected from the Downtown Reach. The total PCBs concentrations in these two samples were 7.41 J and 19.4 J µg/kg (between RM 12 and 13; Map 5.6-7d).

Epibenthic Invertebrates

Seven composite samples of epibenthic invertebrates (mixed taxa) were collected from the Study Area and analyzed for PCBs, with total PCBs concentrations ranging from 33.1 J to 498 µg/kg (maximum concentration between RM 6 and 7; Map 5.6-9a).

Laboratory-Exposed *Lumbriculus* Worms

Thirty-four results were generated by exposing laboratory-reared worms to Study Area sediments, followed by analyses of whole body worms for PCBs. Total PCBs were detected in all samples, with concentrations ranging from 44.8 J to 4,310 J µg/kg (maximum concentration between RM 8 and 9; Map 5.6-14e).

One result was generated by exposing laboratory reared worms to Downstream Reach sediments, followed by analyses of whole body worms for PCBs. Total PCBs were detected at a concentration of 48.9 µg/kg (Multnomah Channel; Map 5.6-14b).

Mussels

Seven composites of resident mussels were collected within the Study Area and submitted to the laboratory for PCB analysis, with concentrations ranging from 5.75 J to 108 J µg/kg (maximum concentration between RM 3 and 4; Map 5.6-9a).

5.6.3 Total PCDD/Fs and TCDD TEQ in Biota

This section presents a summary of the distribution of dioxins/furans in fish and invertebrate tissue by presenting total PCDD/Fs and TCDD TEQ concentrations. Scatter plots showing the distribution of total PCDD/Fs and TCDD TEQ concentrations in select biota tissue collected from the Study Area are provided on Figures 5.6-2a-e and Figures 5.6-3a-e, respectively. Box-whisker plots showing the distribution of total PCDD/Fs and TCDD TEQ concentrations in whole body tissue samples collected of each species across the Study Area are provided on Figure 5.6-16 and Figure 5.6-17, respectively.

5.6.3.1 Total PCDD/Fs and TCDD TEQ in Fish Tissue

Dioxins/furans were detected in all fish tissue types collected from the Study Area that were analyzed for this contaminant. Selected fish species were also collected from the Downstream Reach and the Downtown Reach for dioxin/furan analysis. Species-specific data are summarized below by tissue type. A summary of the results for total PCDD/Fs and TCDD TEQ in fish species collected from the Study Area is presented in Table 5.6-1, from the Downstream Reach in Table 5.6-2, and from the Upriver Reach in Table 5.6-4.

5.6.3.1.1 Total PCDD/Fs in Fish Tissue

A summary of the results of dioxins and furans (expressed as PCDD/Fs) in fish tissue collected from Study Area locations is presented in Table 5.6-1. Similar data for samples collected from the Downstream and Downtown Reaches are presented in Tables 5.6-2 and 5.6-4, respectively. Taxon-specific data are summarized below.

Black Crappie

Individual black crappie samples were collected over a 6-mile reach of the river within the Study Area and were composited for laboratory analysis. A total of four whole body composite samples were submitted for laboratory analysis of dioxins/furans, which were detected in each sample. Total PCDD/Fs concentrations ranged from 7.67 to 16.1 pg/g (maximum concentration between RM 3 and 6; Map 5.6-1a).

Brown Bullhead

Brown bullhead samples were collected over an approximately 6-mile reach of the river within the Study Area and were composited for laboratory analysis. A total of six whole body composite samples were submitted for laboratory analysis of dioxins/furans, which were detected in each sample. Total PCDD/Fs concentrations ranged from 12.2 to 17.8 pg/g (maximum concentration between RM 8 and 10; Map 5.6-2b), and a single composite sample at RM 28 had a total PCDD/Fs concentration of 3.03 pg/g (Table 6.5-4).

Two whole body brown bullhead samples were collected from the Upriver Reach. Total PCDD/Fs concentrations in these samples were 3.03 and 7.45 pg/g (between RM 23 and 24; Map 5.6-15a).

Carp

Six skin-on fillet composite samples of carp were collected within the Study Area and submitted for laboratory analysis of dioxins/furans, which were detected in each sample. Total PCDD/Fs concentrations ranged from 23.1 J to 43.8 J pg/g (maximum concentration between RM 4 and 8; Map 5.6-3b).

Six whole body composite carp samples were submitted for analysis of dioxins/furans, which were detected in each sample. Total PCDD/Fs concentrations ranged from 26.1 to 80.9 pg/g (between RM 8 to 10; Map 5.6-3c). Six whole body composite samples of carp based on combined fillet and body without fillet fractions were also submitted for laboratory analysis of dioxins/furans, which were detected in each sample and the total PCDD/Fs concentrations ranged from 36.7 J to 90.7 J pg/g (RM 4 to 8; Map 5.6-3b). Additionally, six carp body without fillet samples were collected from the Study Area. Dioxins/furans were detected in each sample, with total PCDD/Fs concentrations ranging from 26.1 to 80.9 J pg/g (RM 4 to 8; Map 5.6-3b).

Nine composite carp samples were collected within the Downstream Reach (between RM 0 and 1.9 and Multnomah Channel; Map 5.6-3a) and submitted for analysis of dioxins/furans, which were detected in each sample. Total PCDD/Fs concentrations for three skin-on fillet composite samples ranged from 16.6 J to 26.5 J pg/g. Total PCDD/Fs concentration for three body without fillet composite samples ranged from 31.3 to 49.8 pg/g. Total PCDD/Fs concentrations for three combined fillet and body with out fillet fractions ranged from 27.7 J to 43.9 J pg/g.

Chinook Salmon

Nine juvenile whole body Chinook salmon samples were collected within the Study Area and were composited for laboratory analysis of dioxins/furans, which were detected in each sample. Total PCDD/Fs concentrations ranged from 21.3 J to 42.4 J pg/g (maximum concentration between RM 6 and 7; Map 5.6-4b).

Seven juvenile whole body composite samples were also collected from the Upriver Reach for dioxin/furan analysis. Dioxins/furans were detected in each sample. Total PCDD/Fs concentrations ranged from 1.32 to 6.18 J pg/g (between RM 17 and 18; Map 5.6-16).

Six Chinook salmon samples were collected from the Clackamas River Fish Hatchery and submitted for laboratory analysis of dioxin/furans. Three skin-on fillet samples were analyzed, with total PCDD/Fs concentrations ranging from 1.31 to 1.71 pg/g.

Three fillet without skin samples were analyzed for total PCDD/Fs, with concentrations ranging from 0.652 to 1.09 pg/g.

Lamprey Ammocoetes and Macropthalmia

Six juvenile (ammocoetes and macropthalmia) lamprey samples were collected from the Study Area for dioxin/furan analysis. Dioxins/furans were detected in each sample, with total PCDD/Fs concentrations ranging from 69.1 to 90.1 J pg/g (maximum concentration between RM 1.9 and 6; Map 5.6-8).

Eight juvenile lamprey samples were also collected from the Upriver Reach for dioxin/furan analysis. Dioxins/furans were detected in each sample, with total PCDD/Fs concentrations ranging from 5.6 to 63 pg/g (maximum concentration between RM 18 and 19; Map 5.6-16).

Largescale Sucker

Largescale sucker samples collected within the Study Area and from locations in the Downstream Reach and Upriver Reach were not analyzed for dioxins/furans.

Northern Pikeminnow

Northern pikeminnow samples collected within the Study Area and from locations in the Downstream Reach and Upriver Reach were not analyzed for dioxins/furans.

Peamouth

Peamouth samples collected within the Study Area and from locations in the Downstream Reach and Upriver Reach were not analyzed for dioxins/furans.

Sculpin

Twenty-five whole body composite samples of sculpin were collected and submitted to the laboratory for dioxin/furan analysis. Twenty-one of these samples were collected from the Study Area. Dioxins/furans were detected in each of the samples collected from the Study Area, with total PCDD/Fs concentrations ranging from 6.19 J to 388 pg/g (maximum concentration between RM 7 and 8; Map 5.6-11d).

Two whole body composites were collected from the Downstream Reach, with total PCDD/Fs concentrations of 5.85 J and 8.09 J pg/g (between RM 1 and 2; Map 5.6-11a). Two whole body sculpin composites were also collected in the Downtown Reach for dioxin/furan analysis. Total PCDD/Fs concentrations were 5.27 J and 8.1 J pg/g (between RM 11.8 and 13; Map 5.6-11f).

Smallmouth Bass

Fifty-nine smallmouth bass samples were collected and submitted to the laboratory for dioxin/furan analysis. All but 3 of these samples were collected from the Study Area. Study Area samples included 18 fillet composites, and 20 whole body composites. In addition, concentrations were derived for 18 composites by calculating concentrations for fillet and body without fillet fractions.

Dioxins/furans were detected in all of the samples collected from the Study Area. Total PCDD/Fs concentrations of these Study Area smallmouth bass samples, as presented on Maps 5.6-12a-e, ranged as follows:

- Fillet—0.662 J to 56.9 J pg/g (maximum concentration between RM 6 and 8)
- Combined fillet and body without fillet fractions—5.21 J to 345 J pg/g (RM 6 to 8)
- Body without fillet—7.15 to 433 pg/g (RM 6 to 8)
- Whole body—4.74 to 48.7 pg/g (RM 6 to 8).

Dioxins/furans were detected in the six whole body samples collected from the Downtown and Upriver Reaches, with total PCDD/F concentrations ranging from 3.99 to 10.5 pg/g (maximum concentration between RM 20 and 25; Map 5.6-15a).

Sturgeon

Twenty sturgeon samples were collected from the Study Area and submitted to the laboratory for dioxin/furan analysis. These included 5 composite skin-off fillet of adult sturgeon samples collected by ODHS, EPA, and ATSDR, and 15 juvenile (pre-breeding) sturgeon whole body samples.

As presented on Maps 5.6-13a-b, dioxins/furans were detected in all of the samples. Total PCDD/Fs concentrations of adult sturgeon skin-off fillet samples ranged from 1.64 to 23.2 pg/g (maximum concentration at RM 6; Map 5.6-13a). Juvenile sturgeon whole body total PCDD/Fs concentrations ranged from 4.32 J to 13.9 J pg/g (maximum concentration between RM 3 and 4; Map 5.6-13a).

5.6.3.1.2 TCDD TEQ in Fish Tissue

A summary of the results of dioxins and furans (expressed as TCDD TEQ) in fish tissue collected from Study Area locations is presented in Table 5.6-1. Similar data for samples collected from the Downstream Reach, and from the Downtown and Upriver Reaches are presented in Tables 5.6-2 and 5.6-4, respectively. Taxon specific data are summarized below.

Black Crappie

Individual black crappie samples were collected over a 6-mile reach of the river within the Study Area and were composited for laboratory analysis. A total of four whole body composite samples were submitted for laboratory analysis of dioxins/furans, which were detected in each sample. TCDD TEQ ranged from 1.1 J to 1.26 J pg/g (maximum concentration between RM 3 and 6; Map 5.6-1a).

Brown Bullhead

Brown bullhead samples were collected over an approximately 6-mile reach of the river within the Study Area and were composited for laboratory analysis. A total of six whole body composite samples were submitted for laboratory analysis of dioxins/furans, which were detected in each sample. TCDD TEQ ranged from 1.29 J to 2.12 J pg/g (maximum concentration between RM 6 and 9; Map 5.6-2b).

Three whole body brown bullhead samples were collected from the Upriver Reach. TCDD TEQ in those samples ranged from 0.807 J to 2.9 J pg/g (maximum concentration between RM 23 and 24; Map 5.6-15a).

Carp

Six skin-on fillet composite samples of carp were collected within the Study Area and submitted for laboratory analysis of dioxins/furans, which were detected in each sample. TCDD TEQ ranged from 2.07 J to 4.37 J pg/g (RM 4 to 8; Map 5.6-3b).

Six whole body composite carp samples were collected from the Study Area and submitted for analysis of dioxins/furans, which were detected in each sample. TCDD TEQ ranged from 1.98 to 8.53 pg/g (RM 3 to 6; Map 5.6-3b). Six whole body composite samples of carp based on combined fillet and body without fillet fractions were also submitted for laboratory analysis of dioxins/furans, which were detected in each sample. TCDD TEQ in those samples ranged from 3.15 J to 6.3 J pg/g (RM 5 to 6; Map 5.6-3b). Additionally, six carp body without fillet samples were collected from the Study Area. Dioxins/furans were detected in each sample, with TCDD TEQ ranging from 3.51 J to 6.99 J pg/g (RM 4 to 7; Map 5.6-3b).

Nine composite carp samples were collected within the Downstream Reach (between RM 0 and 1.9 and Multnomah Channel; Map 5.6-3a) and submitted for analysis of dioxins/furans, which were detected in each sample. TCDD TEQ for three skin-on fillet composite samples ranged from 1.88 J and 2.59 J pg/g. TCDD TEQ for three body without fillet composite samples ranged from 2.76 to 3.47 J pg/g. TCDD TEQ for three combined fillet and body with out fillet fractions ranged from 2.54 J pg/g to 3.23 J pg/g.

Chinook Salmon

Nine juvenile Chinook salmon whole body samples were collected within the Study Area and were composited for laboratory analysis of dioxins/furans, which were detected in each sample. TCDD TEQ in those samples ranged from 1.2 J to 4.37 J pg/g (maximum concentration between RM 6 and 7; Map 5.6-4b).

Seven juvenile whole body composite samples were also collected from the Downtown and Upriver Reaches for dioxin/furan analysis. Dioxins/furans were detected in each sample. TCDD TEQ ranged from 0.102 to 1.12 J pg/g (between RM 15 and 26; Map 5.6-16).

Three skin-on fillet samples and three skin-off fillet samples were also collected from the Clackamas River Fish Hatchery. TCDD TEQ in the skin-on samples ranged from 0.143 to 0.171 pg/g. TCDD TEQ in the skin-off samples ranged from 0.0506 to 0.157 pg/g.

Lamprey Ammocoetes and Macropthalmia

Six juvenile (ammocoetes and macropthalmia) lamprey samples were collected within the Study Area for dioxin/furan analysis. Dioxins/furans were detected in each sample, with TCDD TEQ concentrations ranging from 2.36 J to 4.18 J pg/g (maximum concentration from RM 9 and 11.8; Map 5.6-8).

Eight juvenile lamprey samples were also collected from the Upriver Reach for dioxin/furan analysis. Dioxins/furans were detected in each sample, with TCDD TEQ ranging from 0.218 to 3.1 J pg/g (between RM 15 and 26; Map 5.6-16).

Largescale Sucker

Largescale sucker samples collected within the Study Area and from locations in the Downstream Reach and Upriver Reach were not analyzed for dioxins/furans.

Northern Pikeminnow

Northern pikeminnow samples collected within the Study Area and from locations in the Downstream Reach and Upriver Reach were not analyzed for dioxins/furans.

Peamouth

Peamouth samples collected within the Study Area and from locations in the Downstream Reach and Upriver Reach were not analyzed for dioxins/furans.

Sculpin

Twenty-five whole body composite samples of sculpin were collected and submitted to the laboratory for dioxin/furan analysis. Twenty-one of these samples were collected from the Study Area. Dioxins/furans were detected in each of the samples collected from the Study Area, with TCDD TEQ ranging from 0.618 J to 31.8 pg/g (RM 7 to 8; Map 5.6-11d).

Two whole body composites were collected from the Downstream Reach, with TCDD TEQ of 0.528 J and 0.946 J pg/g (between RM 0 and 1.9; Map 5.6-11a). Two whole body sculpin composites were also collected from the Downtown Reach for dioxin/furan analysis. TCDD TEQ was 0.617 J and 0.856 J pg/g (between RM 11.8 and 12; Map 5.6-11f).

Smallmouth Bass

Fifty-six smallmouth bass samples were collected and submitted to the laboratory for dioxin/furan analysis. All but 6 of these samples were collected from the Study Area. Study Area samples included 18 composites of body without fillet, 18 fillet composites, and 14 whole body composites. In addition, concentrations were derived for 18 composites by calculating concentrations for fillet and body without fillet fractions.

Dioxins/furans were detected in all of the samples collected from the Study Area. TCDD TEQ of these Study Area smallmouth bass samples, as presented on Maps 5.6-12a-e, ranged as follows:

- Fillet—0.187 J to 8.74 J pg/g (RM 6 to 8)
- Combined fillet and body without fillet fractions—1.26 J to 51.9 J pg/g (RM 6 to 8)
- Body without fillet—1.67 J to 64.9 J pg/g (RM 6 to 8)
- Whole body—1.29 J to 7.77 pg/g (RM 6 to 8).

Dioxins/furans were detected in the six whole body samples collected from the Downtown and Upriver Reaches, with TCDD TEQ ranging from 0.905 J to 2.45 J pg/g (maximum concentration between RM 19 and 24; Map 5.6-15a).

Sturgeon

Twenty sturgeon samples were collected from the Study Area and submitted to the laboratory for dioxin/furan analysis. These included 5 composite skin-off fillet samples and 15 whole body samples.

As presented on Maps 5.6-13a-b, dioxins/furans were detected in all of the samples. TCDD TEQ of the skin-off fillet samples ranged from 0.135 to 1.33 pg/g (maximum concentration between RM 6 and 7; Map 5.6-13a). Whole body TCDD TEQ ranged from 0.35 J to 1.33 J pg/g (maximum concentration between RM 3 and 4; Map 5.6-13b).

5.6.3.2 Total PCDD/Fs and TCDD TEQ in Invertebrate Tissue

Dioxins/furans were detected in all invertebrate species and tissue types collected from the Study Area for which dioxin/furan analysis was conducted. Selected invertebrate species were also collected from the Downstream, Downtown, and Upriver Reaches. Taxon-specific data are summarized below. A summary of the results for total PCDD/Fs and TCDD TEQ in invertebrate tissue collected from the Study Area is presented in Table 5.6-5, from the Downstream Reach in Table 5.6-6, and from the Downtown and Upriver Reaches in Table 5.6-7.

5.6.3.2.1 Total PCDD/Fs in Invertebrate Tissue

A summary of the results of dioxins and furans (expressed as total PCDD/Fs) in invertebrate tissue collected from Study Area locations is presented in Table 5.6-5. Similar data for samples collected from the Downstream Reach and from the Downtown and Upriver Reaches are presented in Tables 5.6-6 and 5.6-7, respectively. Taxon-specific data are summarized below.

Clams (Resident)

All clam samples consisted of composited soft parts only (body without shell). Thirty-five composite samples of resident clams (non-depurated) were collected within the Study Area and submitted to the laboratory for dioxin/furan analysis. Dioxins/furans were detected in all of the samples, with total PCDD/Fs concentrations ranging from 25.3 J to 189 pg/g (maximum concentration from RM 7 to 8; Map 5.6-5d). Three additional depurated samples were collected within the Study Area for dioxin/furan analysis. Dioxins/furans were detected in each sample, with total PCDD/Fs concentrations ranging from 24.3 J to 42.5 J pg/g (maximum concentration from RM 10 to 11; Map 5.6-5f).

Three composite clam samples, one depurated and two not depurated, were collected from the Downstream Reach. Dioxins/furans were detected in the depurated sample with a total PCDD/Fs concentration of 29.3 J pg/g and in the non-depurated samples at concentrations of 33.2 J and 39 pg/g (between RM 0 and 1.9 and Multnomah Channel; Maps 5.6-5a-b).

Three composite clam samples, one depurated and two not depurated, were also collected from the Downtown Reach. Dioxins/furans were detected in the depurated sample with a total PCDD/Fs concentration of 25.9 J pg/g and in the non-depurated samples at concentrations of 33.4 J and 36.6 J pg/g (between RM 10 and 12; Map 5.6-5f).

Clams (Laboratory-Exposed)

Thirty-four additional clam results were generated by exposing laboratory-reared clams to Study Area sediments, followed by chemical analysis of soft body parts for dioxins/furans, which were detected in all of the samples. Total PCDD/Fs concentrations ranged from 4.48 J to 696 J pg/g (maximum concentration between RM 6 and 7; Map 5.6-6d). One clam result was generated by exposing laboratory reared clams to Downstream Reach sediments. Total PCDD/Fs concentration was 4.83 pg/g (Multnomah Channel; Map 5.6-6b).

Crayfish

Fifteen whole body crayfish composites were collected within the Study Area and submitted to the laboratory for dioxin/furan analysis. Dioxins/furans were detected in all of the samples, with total PCDD/Fs concentrations ranging from 12.1 J to 281 pg/g (RM 7 to 8; Map 5.6-7c).

Two composite whole body crayfish samples were collected from the Downstream Reach. Dioxins/furans were detected, with total PCDD/Fs concentrations of 11.3 and 12.4 pg/g. (between RM 1 and 1.9; Map 5.6-7a).

Two composite whole body crayfish samples were also collected from the Downtown Reach. Dioxins/furans were detected, with total PCDD/Fs concentrations of 9.46 and 14 pg/g (between RM 11 and 12; Map 5.6-7d).

Epibenthic Invertebrates

Seven composite samples of epibenthic invertebrates (mixed taxa) were collected from the Study Area and analyzed for dioxins/furans, with total PCDD/Fs concentrations ranging from 49.1 to 213 pg/g (maximum concentration between RM 9 and 10; Map 5.6-9b).

Laboratory-Exposed *Lumbriculus* Worms

Thirty-four results were generated by exposing laboratory-reared *Lumbriculus* worms to Study Area sediments, followed by chemical analyses of whole body worms for dioxins/furans, which were detected in all of the samples. Total PCDD/Fs concentrations in these laboratory exposed samples ranged from 51 J to 6,440 pg/g (maximum concentration from sediments collected between RM 6 and 7; Map 5.6-14d).

One result was generated by exposing laboratory-reared worms to Downstream Reach sediments, followed by chemical analyses of whole body worms for dioxins/furans. The total PCDD/Fs concentration in the laboratory-exposed sample was 68.1 J pg/g (Multnomah Channel; Map 5.6-14b).

Mussels

Seven composites of resident mussels were collected within the Study Area and submitted to the laboratory for dioxin/furan analysis. Dioxins/furans were detected in each sample, with total PCDD/Fs concentrations ranging from 14.4 J to 66.2 J pg/g (maximum concentration between RM 3 and 4; Map 5.6-9a).

5.6.3.2.2 TCDD TEQ in Invertebrate Tissue

A summary of the results of dioxins and furans (expressed as TCDD TEQ) in invertebrate tissue collected from Study Area locations is presented in Table 5.6-5. Similar data for samples collected from the Downstream Reach, and from the Downtown Reach and Upriver Reach are presented in Tables 5.6-6 and 5.6-7, respectively. Taxon-specific data are summarized below.

Clams (Resident)

All clam samples consisted of composites of soft parts only (body without shell). Thirty-nine composite samples of resident clams (non-depurated) were collected within the Study Area and submitted to the laboratory for dioxin/furan analysis. Dioxins/furans were detected in all of the samples, with TCDD TEQs ranging from 0.0963 J to 5.45 J pg/g (maximum concentration between RM 7 and 8; Map 5.6-5d). Five additional depurated samples were collected within the Study Area for dioxin/furan analysis. Dioxins/furans were detected in each sample, with TCDD TEQs ranging from 0.139 J to 0.367 J pg/g (maximum concentration between RM 2 and 3; Map 5.6-5b).

Three composite clam samples, one depurated and two not depurated, were collected from the Downstream Reach. Dioxins/furans were detected in a single depurated sample with a TCDD TEQ of 0.192 J pg/g and in the non-depurated samples with TCDD TEQs of 0.0963 J and 0.379 J pg/g (between RM 0 and 1.9 and Multnomah Channel; Maps 5.6-5a-b).

Three composite clam samples, one depurated and two not depurated, were also collected from the Downtown Reach. Dioxins/furans were detected in the depurated sample with a TCDD TEQ of 0.22 J pg/g and in the non-depurated samples at 0.215 J and 0.318 J pg/g (between RM 10 and 12; Map 5.6-5f).

Clams (Laboratory-Exposed)

Thirty-four additional clam results were generated by exposing laboratory-reared clams to Study Area sediments, followed by chemical analysis of soft body parts for dioxins/furans, which were detected in all of the samples. TCDD TEQs ranged from 0.00911 J to 40.5 J pg/g (maximum concentration from sediments collected between RM 6 and 7; Map 5.6-6d).

One clam result was generated by exposing laboratory-reared clams to Downstream Reach sediments, followed by chemical analysis of soft body parts for dioxins/furans. TCDD TEQ was 0.000714 J pg/g (Multnomah Channel; Map 5.6-6b).

Crayfish

Fifteen whole body crayfish composites were collected within the Study Area and submitted to the laboratory for dioxin/furan analysis. Dioxins/furans were detected in all of the samples, with TCDD TEQs ranging from 0.203 J to 18.2 pg/g (RM 7 to 8; Map 5.6-7c).

Two composite whole body crayfish samples were collected from the Downstream Reach. Dioxins/furans were detected, with TCDD TEQs of 0.21 J and 0.321 J pg/g (between RM 0 and 1.9; Map 5.6-7a).

Two composite whole body crayfish samples were also collected from the Downtown Reach. Dioxins/furans were detected, with TCDD TEQs of 0.283 J and 0.485 J pg/g (between RM 11 and 12; Map 5.6-7d).

Epibenthic Invertebrates

Seven composite samples of epibenthic invertebrates (mixed taxa) were collected from the Study Area and analyzed for dioxins/furans, with TCDD TEQs ranging from 0.275 J to 3.34 J pg/g (maximum concentration between RM 6 and 7; Map 5.6-9a).

Laboratory-Exposed *Lumbriculus* Worms

Thirty-four results were generated by exposing laboratory-reared *Lumbriculus* worms to Study Area sediments, followed by chemical analyses of whole body worms for dioxins/furans, which were detected in all of the samples. TCDD TEQs in these laboratory-exposed samples ranged from 0.743 J to 448 J pg/g (maximum concentration from sediments collected between RM 6 and 7; Map 5.6-14d).

One result was generated by exposing laboratory-reared *Lumbriculus* worms to Downstream Reach sediments, followed by chemical analyses of whole body worms for dioxins/furans. TCDD TEQ in this laboratory-exposed sample was 1.24 J pg/g (Multnomah Channel; Map 5.6-14b).

Mussels

Seven composites of resident mussels were collected within the Study Area and submitted to the laboratory for dioxin/furan analysis. Dioxins/furans were detected in each sample, with TCDD TEQs ranging from 0.0704 J to 0.446 J pg/g (maximum concentration between RM 3 and 4; Map 5.6-9a).

5.6.4 Total DDx in Biota

This section presents a summary of the distribution of total DDx in fish and invertebrate tissue. The distributions of DDx compounds—the sum of ortho (2,4'-) and para (4,4'-) isomers of DDD, DDE, and DDT—are described in this section, including concentration trends and DDx analyte patterns in tissue samples from the Study Area. Scatter plots showing the distribution of total DDx concentrations in select biota tissue collected from the Study Area are provided on Figures 5.6-4a-e. A box-whisker plot showing the distribution of total DDx for each species and tissue type is provided on Figure 5.6-18.

5.6.4.1 Total DDx in Fish Tissue

As shown in Table 5.6-1, DDx compounds, expressed as total DDx, were detected in all fish samples collected from the Study Area except some Chinook salmon fillet samples and some whole body lamprey samples. Selected fish species were also collected from the outlying reaches. A summary of the results in fish tissue collected from locations within the Downstream Reach is presented in Table 5.6-2-and from the Downtown and Upriver Reaches in Table 5.6-4. Species-specific data are summarized below, by tissue type.

Black Crappie

Four fillet and four whole body composite black crappie samples were collected from the Study Area and submitted for laboratory analyses of DDx. DDx was detected in all four fillets, with total DDx concentrations ranging from 8.8 J to 13.7 J µg/kg (maximum concentration between RM 6 and 9; Map 5.6-1b).

DDx was also detected in all four whole body samples, with total DDx concentrations ranging from 59.2 J to 99.6 J µg/kg (maximum concentration between RM 6 and 9; Map 5.6-1b).

Brown Bullhead

Six skin-off fillet composite samples and 6 whole body composite samples of brown bullhead were collected from the Study Area and submitted for laboratory analyses of DDx. DDx was detected in all 12 samples, with fillet total DDx concentrations ranging from 12 J to 26.5 J µg/kg (maximum concentration between RM 6 and 9; Map 5.6-2b).

DDx was also detected in all six whole body samples, with total DDx concentrations ranging from 37.5 J to 141 J µg/kg (maximum concentration between RM 6 and 9; Map 5.6-2b).

Three whole body brown bullhead composites were also collected from the Upriver Reach, with total DDx concentrations ranging from 18 J to 52 J µg/kg (between RM 23 and 24; Map 5.6-15a).

Carp

Twelve skin-on fillet composite samples of carp were collected and submitted for laboratory analyses of DDx. DDx was detected in all Study Area samples, with concentrations ranging from 47.3 J to 494 J µg/kg (RM 4 to 8; Map 5.6-3b).

Twelve composite samples of carp designated as whole body samples were also submitted for laboratory analyses of DDx. These 12 samples included 6 whole body samples and 6 samples based on combined fillet and body without fillet fractions. DDx was detected in all 12 samples, with total DDX concentrations ranging from 73.3 J to 615 J µg/kg (RM 4 to 8; Map 5.6-3b).

The six composite carp samples of body without fillet had a range of total DDx concentration between 83.4 J to 658 J µg/kg, also collected between RM 6 and 8 (Map 5.6-3b).

Nine composite carp samples were collected within the Downstream Reach and submitted for analysis of DDx, which were detected in each sample. Total DDx for three skin-on fillet composite samples ranged from 70 J to 113 µg/kg. Total DDx for three body without fillet composite samples ranged from 101 to 149 µg/kg. Total DDx for three composite samples of combined fillet and body without fillet fractions ranged from 93.3 J to 140 µg/kg (between RM 0 and 1.9 and Multnomah Channel; Map 5.6-3a).

Chinook Salmon

Fifteen juvenile whole body Chinook salmon samples were collected within the Study Area and were composited for laboratory analyses of DDx. DDx was detected in all 15 samples, with total DDx concentrations ranging from 16.9 J to 284 µg/kg (maximum concentration between RM 6 and 7; Map 5.6-4b).

Eight juvenile whole body composite samples were also collected from the Upriver Reach, with concentrations of total DDx ranging from 5.4 to 12.2 J µg/kg (between RM 17 and 18; Map 5.6-16).

Also collected from the Clackamas River Fish Hatchery were three fillet samples, with DDx being detected in two of the three samples. Total DDx concentrations in these two fillet samples were 10.9 J and 12 J µg/kg.

Five composites of juvenile Chinook salmon were collected from the Study Area and submitted for DDx analyses of stomach contents. Total DDx was detected in all five samples, with concentrations ranging from 8.88 J to 327 J µg/kg (maximum concentration between RM 6 and 7; Map 5.6-4b).

Stomach contents of the single composite sample collected from the Upriver Reach contained 6.61 J µg/kg of total DDx (between RM 17 and 18; Map 5.6-16).

Lamprey Ammocoetes and Macropthalmia

Fourteen juvenile (ammocoetes and macropthalmia) lamprey samples were collected within the Study Area and were composited for DDx analyses. DDx was detected in all six samples collected from the Study Area, with total DDx concentrations ranging from 42.3 to 121 µg/kg (macropthalmia; RM 2 to 3; Map 5.6-8). DDx was also detected in four of eight composite samples collected from the Upriver Reach, and total DDx concentrations in those four composite samples ranged from 36.8 to 77.1 µg/kg (maximum concentration between RM 18 and 19; Map 5.6-16).

Largescale Sucker

Six whole body composites of largescale sucker were collected from the Study Area and submitted to the laboratory for DDx analyses. Total DDx concentrations were detected in all six samples, and concentrations ranged from 143 J to 670 µg/kg (maximum concentration between RM 8 and 9; Map 5.6-10b).

Northern Pikeminnow

Six whole body composites of northern pikeminnow were collected from the Study Area and submitted to the laboratory for DDx analyses. Total DDx concentrations of these six samples ranged from 145 to 761 µg/kg (maximum concentration between RM 6 and 7; Map 5.6-10a).

Peamouth

Four whole body composites of peamouth were collected from the Study Area and submitted to the laboratory for DDx analyses. Total DDx was detected in each of these samples, and concentrations ranged from 132 J to 215 µg/kg (maximum concentration between RM 8 and 9; Map 5.6-10b).

Sculpin

Forty-two whole body composite samples of sculpin were collected and submitted to the laboratory for DDx analyses. Thirty-eight of these samples were collected from the Study Area, with total DDx concentrations ranging from 12.7 J to 3,060 µg/kg (RM 7 to 8; Map 5.6-11d).

Two composites were collected from the Downstream Reach, with total DDx concentrations of 25 J and 37.8 µg/kg (between RM 0 and 1.9; Map 5.6-11a). Two whole body sculpin composites were also collected from the Downtown Reach, with total DDx concentrations of 13.5 J and 15 J µg/kg (between RM 11 and 12; Map 5.6-11f).

Smallmouth Bass

Sixty-one smallmouth bass samples were collected and submitted to the laboratory for DDx analyses. All but 6 of these samples were collected from the Study Area. Study Area samples included 18 composites of body without fillet, 23 fillet composites, and

14 whole body composites. In addition, concentrations were derived for 18 composites by calculating concentrations for fillet and body without fillet fractions.

Total DDx concentrations of these Study Area smallmouth bass samples ranged as follows:

- Fillet—6.41 J to 181 µg/kg (RM 6 to 7; Map 5.6-12c2)
- Combined fillet and body without fillet fractions—34.5 J to 1,460 µg/kg (RM 6 to 7; Map 5.6-12c2)
- Body without fillet—43.1 J to 1,840 µg/kg (RM 6 to 7; Map 5.6-12c2)
- Whole body—65 J to 408 µg/kg (RM 6 to near 8; Map 5.6-12c2).

Total DDx concentrations of the six composites collected from the Downtown and Upriver Reaches ranged from 56.9 J to 120 J µg/kg (maximum concentration between RM 20 and 25; Map 5.6-15a).

Sturgeon

Twenty-one sturgeon samples were collected from the Study Area and submitted to the laboratory for DDx analyses. These included 5 composite skin-off fillet samples, 15 whole body samples, and 1 sample for stomach contents.

Whole body total DDx concentrations ranged from 77.9 to 176 J µg/kg (maximum concentration between RM 6 and 8; Map 5.6-13b). Total DDx concentrations of skin-off fillet samples ranged from 38 J to 125 J µg/kg (maximum concentration between RM 6 and 7; Map 5.6-13a). The total DDx concentration of the single stomach contents sample equaled 3.61 J µg/kg (between RM 7 and 8; Map 5.6-13b).

5.6.4.2 Total DDx in Invertebrate Tissue

DDx compounds were detected in all invertebrate types collected from the Study Area. Selected invertebrate species were also collected at the Downstream Reach, Downtown Reach, and Upriver Reach. A summary of the results for total DDx in invertebrate tissue collected from the Study Area is presented in Table 5.6-5, from the Downstream Reach in Table 5.6-6, and from the Downtown and Upriver Reaches in Table 5.6-7. Taxon-specific data are summarized below.

Clams (Resident)

All resident clam samples consisted of composites of soft parts only (body without shell). Forty composites of resident clams (non-depurated) were collected within the Study Area and submitted to the laboratory for DDx analyses, with total DDx concentrations ranging from 7.44 J to 463 J µg/kg (maximum concentration between RM 7 and 8; Map 5.6-5d). Three additional depurated samples were collected within the Study Area, with total DDx concentrations ranging from 6.04 J to 27.8 µg/kg (maximum concentration between RM 2 and 3; Map 5.6-5b).

Three composite clam samples, one depurated and two not depurated, were collected from the Downstream Reach. The total DDx concentrations in the non-depurated samples were 22.8 and 28.5 µg/kg, while the total DDx concentration of the depurated sample was 23.1 µg/kg (between RM 0 and 1.9 and Multnomah Channel; Maps 5.6-5a-b).

Three composite clam samples, one depurated and two not depurated, were also collected from the Downtown Reach. The total DDx concentrations in the non-depurated samples were 8.65 and 9.35 J µg/kg. The total DDx concentration of the depurated sample was 7.01 J µg/kg (between RM 11 and 12.3; Map 5.6-5f).

Clams (Laboratory-Exposed)

Thirty-four additional clam results were generated by exposing laboratory-reared clams to Study Area sediments, followed by analyses of soft body parts for DDx. The total DDx concentrations of these 35 laboratory-exposed samples ranged from 1.13 J to 1,040 µg/kg (maximum concentration from sediments collected between RM 7 and 8; Map 5.6-6d).

One clam result was generated by exposing laboratory-reared clams to Downstream Reach sediments, followed by analyses of soft body parts for DDx. The total DDx concentration of this one sample was 1.23 J µg/kg (Multnomah Channel; Map 5.6-6b).

Crayfish

Thirty-two whole body crayfish composites were collected within the Study Area and submitted to the laboratory for DDx analyses. DDx compounds were detected in all samples, with total DDx concentrations ranging from 1.12 J to 84.9 J µg/kg (RM 7 to 8; Map 5.6-7c).

Two composite whole body crayfish samples were collected from the Downstream Reach. The total DDx concentrations in these two samples were 2.62 J and 3.17 J µg/kg (between RM 1 and 2; Map 5.6-7a).

Two composite whole body crayfish samples were also collected from the Downtown Reach. The total DDx concentrations in these two samples were 1.75 J and 2.47 J µg/kg (between RM 12 and 12.3; Map 5.6-7d).

Epibenthic Invertebrates

Seven composite samples of epibenthic invertebrates (mixed taxa) were collected from the Study Area and analyzed for DDx, with concentrations ranging from 2.67 to 94.8 µg/kg (maximum concentration between RM 6 and 7; Map 5.6-9a).

Laboratory-Exposed *Lumbriculus* Worms

Thirty-four results were generated by exposing laboratory-reared *Lumbriculus* worms to Study Area sediments, followed by analyses of whole body worms for DDx. DDx compounds were detected in all samples, with total DDx concentrations ranging from 14.5 J to 1,490 µg/kg (maximum concentration between RM 6 and 7; Map 5.6-14d).

One result was generated by exposing laboratory-reared *Lumbriculus* worms to Downstream Reach sediments, followed by analyses of whole body worms for DDx. Total DDx concentrations were 24.4 J µg/kg (Multnomah Channel; Map 5.6-14b).

Mussels

Seven composites of resident mussels were collected within the Study Area and submitted to the laboratory for DDx analyses, with detected total DDx concentrations in all samples ranging from 0.979 J to 4.44 J µg/kg (maximum concentration between RM 8 and 9; Map 5.6-9b).

5.6.5 Total PAHs in Biota

This section presents a summary of the distribution of total PAHs in fish and invertebrate tissue. Scatter plots showing the distribution of PAHs concentrations in select biota tissue collected from the Study Area are provided on Figures 5.6-5. A box-whisker plot showing the distribution of PAHs concentrations in whole body tissue samples collected of each species across the Study Area is provided on Figure 5.6-19.

5.6.5.1 Total PAHs in Fish Tissue

As shown in Table 5.6-1, PAHs were detected in all fish samples collected from the Study Area that were analyzed for this class of contaminants. Selected fish species were also collected from the Downstream, Downtown, and Upriver Reaches for PAH analyses. A summary of the total PAHs results in fish tissue collected from locations from the Downstream Reach is presented in Table 5.6-2 and from the Downtown and Upriver Reaches in Table 5.6-4. Species-specific data are summarized below by tissue type.

Black Crappie

Black crappie samples collected from the Study Area were not analyzed for PAHs.

Brown Bullhead

A total of six skin-off fillet composite samples were submitted for laboratory analyses of PAHs. PAHs were detected in two of the samples, with total PAHs concentrations of 110 J and 250 µg/kg (maximum concentration between RM 3 and 6; Map 5.6-2a).

A total of six whole body composite samples were submitted for laboratory analyses of PAHs. PAHs were detected in one sample, with a total PAHs concentration of 100 µg/kg (maximum concentration between RM 3 and 6; Map 5.6-2a).

Three whole body brown bullhead were collected from the Upriver Reach. Total PAHs were not present in any of the samples.

Carp

Six skin-on fillet composite samples of carp were collected within the Study Area and submitted for laboratory analyses of PAHs. PAHs were detected in all six samples, with total PAHs concentrations ranging from 11 to 140 µg/kg (RM 4 to 8; Maps 5.6-3a-b).

Twelve whole body composite samples of carp were also submitted for laboratory analyses of PAHs. These 12 samples included 6 whole body samples and 6 samples based on combined fillet and body without fillet fractions. PAHs were detected in all but 4 of the whole body samples, with total PAHs concentrations ranging from 11 J to 222 J µg/kg (between RM 8 to 12; Map 5.6-3 c). Additionally, 6 carp body without fillet samples were collected from the Study Area. PAHs were detected in each sample, with total PAHs concentrations ranging from 10 to 170 µg/kg (RM 4 to 12; Maps 5.6-3—b-c).

Nine composite carp samples were collected within the Downstream Reach (between RM 0 and 1.9 and Multnomah Channel; Map 5.6-3a) and submitted for analysis of PAHs, which were detected in each sample. Total PAHs for three skin-on fillet composite samples ranged from 30 to 42 µg/kg. Total PAHs for three body without fillet composite samples ranged from 33 J to 50 µg/kg. Total PAHs for three composite samples of combined fillet and body with out fillet fractions ranged from 41 J to 53 J µg/kg.

Chinook Salmon

Fifteen juvenile whole body Chinook salmon samples were collected within the Study Area and were composited for laboratory analyses of PAHs. PAHs were detected in 10 samples out of 15, with total PAHs concentrations ranging from 9.96 J to 33 µg/kg (maximum concentration between RM 2 and 3; Map 5.6-4a).

Eight juvenile whole body composite samples were also collected from the Upriver Reach. PAHs were detected in six samples, with total PAH concentrations ranging from 5.2 J to 10.1 J µg/kg (between RM 17 and 18; Map 5.6-16).

Also collected from the Clackamas River Fish Hatchery were three skin-on fillet samples. PAHs were detected in two of the samples, with total PAH concentrations of 1.8 J and 5.4 J µg/kg.

Five composites of juvenile Chinook salmon were collected from the Study Area and submitted for PAH analyses of stomach contents. PAHs were detected in all samples, with total PAHs ranging from 95.5 J to 2,460 J µg/kg (maximum concentration between RM 6 and 7; Map 5.6-4b).

Stomach contents of the single composite sample collected from the Upriver Reach contained a total PAHs concentration of 87.4 J µg/kg (between RM 17 and 18; Map 5.6-16).

Lamprey Ammocoetes and Macropthalmia

Three juvenile (ammocoetes and macropthalmia) lamprey samples were collected within the Study Area for PAH analyses. PAHs were detected in each sample, with total PAH concentrations ranging from 48 J to 270 J µg/kg (ammocoete composite maximum concentration between RM 1.9 and 6; Map 5.6-8). PAHs were also detected in all four composite samples collected from the upriver reach, and total PAHs in those composite samples ranged from 18 to 41 µg/kg (maximum concentration between RM 18 and 19; Map 5.6-16).

Largescale Sucker

Six whole body composites of largescale sucker were collected from the Study Area and submitted to the laboratory for PAH analyses. PAHs were detected in two of the six samples, with total PAH concentrations of 42 J and 147 J µg/kg (maximum concentration with RM 6 and 8; Map 5.6-10a).

Northern Pikeminnow

Northern pikeminnow samples collected within the Study Area and from locations in the Downstream Reach and Upriver Reach were not analyzed for PAHs.

Peamouth

Peamouth samples collected within the Study Area and from locations in the Downstream Reach and Upriver Reach were not analyzed for PAHs.

Sculpin

Forty-two whole body composite samples of sculpin were collected and submitted to the laboratory for PAH analyses. Thirty-eight of these samples were collected from the Study Area. PAHs were detected in 22 of the 38 samples collected from the Study Area. Total PAHs concentrations ranged from 7.8 J to 550 µg/kg (RM 6 to 12; Maps 5.6-11d-f).

Two whole body composites were collected from the Downstream Reach, with total PAHs concentrations of 13 and 18 µg/kg (between RM 0 and 1.9; Map 5.6-11a). Two whole body sculpin composites were also collected from the Downtown Reach, with total PAHs concentrations of 9.2 and 31 µg/kg (between RM 11.7 and 12.3; Map 5.6-11f).

Smallmouth Bass

Fifty-six smallmouth bass samples were collected and submitted to the laboratory for PAH analyses. All but 6 of these samples were collected from the Study Area. Study Area samples included 18 composites of body without fillet, 18 fillet composites, and 14 whole body composites. In addition, concentrations were derived for 18 composites by calculating concentrations for fillet and body without fillet fractions.

PAHs were detected in all but seven of the whole body samples collected from the Study Area. Total PAH concentrations of these Study Area smallmouth bass samples, as presented on Maps 5.6-12a-e, ranged as follows:

- Fillet—0.58 to 84 µg/kg (RM 8 to 9)
- Combined fillet and body without fillet fractions—11 to 180 µg/kg (RM 5 to 6)
- Body without fillet—5.2 to 230 µg/kg (RM 6 to 7)
- Whole body—31 to 308 µg/kg (RM 6 to 8).

PAHs were not detected in the six whole body samples collected from the Downtown and Upriver Reaches.

Sturgeon

Twenty-three sturgeon samples were collected from the Study Area and submitted to the laboratory for PAH analyses. These included 5 composite skin-off fillet samples, 15 whole body samples, and 3 samples of stomach contents.

As presented on Maps 5.6-13a-b, total PAHs were detected in all of the samples, with the exception of two of the fillet samples. Total PAHs concentrations of skin-off fillet samples ranged from 4 J to 23.1 µg/kg (maximum concentration between RM 5 and 6). Whole body total PAHs concentrations ranged from 1.1 to 61 µg/kg (maximum concentration between RM 6 and 7). Total PAHs were detected in all three stomach contents samples, and concentrations ranged from 3.6 to 9,000 µg/kg (maximum concentration between RM 6 and 7).

5.6.5.2 Total PAHs in Invertebrate Tissue

PAHs were detected in all invertebrate species and tissue types collected from the Study Area for which analysis was conducted. Selected invertebrate species were also collected above and below the Study Area. A summary of the results for total PAHs in invertebrate tissue collected from the Study Area is presented in Table 5.6-5, from the Downstream Reach in Table 5.6-6, and from the Downtown and Upriver Reaches in Table 5.6-7. Taxon-specific data are summarized below.

Clams (Resident)

All clam samples consisted of soft parts only (body without shell). Thirty-nine composites of resident clams (non-depurated) were collected within the Study Area and submitted to the laboratory for PAH analyses, with total PAHs concentrations ranging from 23 to 4,980 µg/kg (RM 6 to 7; Map 5.6-5d). Three additional depurated samples were collected within the Study Area, with total PAHs concentrations ranging from 30 to 220 µg/kg (RM 2 to 3; Map 5.6-5b).

Three composite clam samples, one depurated and two not depurated, were collected from the Downstream Reach. The total PAHs concentrations in the non-depurated samples were 95 and 551 µg/kg, while the total PAHs concentration in the depurated sample was 76 µg/kg (between RM 0 and 1.9 and Multnomah Channel; Maps 5.6-5a-b).

Three composite clam samples, one depurated and two not depurated, were also collected from the Downtown Reach. The total PAHs concentrations in the non-depurated samples were 22 µg/kg and 110 µg/kg. The total PAHs concentration of the depurated sample from above the Study Area was 23 J µg/kg (between RM 11 and 12.2; Map 5.6-5f).

Clams (Laboratory-Exposed)

Thirty-four additional clam results were generated by exposing laboratory-reared clams to Study Area sediments, followed by laboratory analyses of soft body parts for PAHs. Total PAHs were detected in each sample, with concentrations of these 34 laboratory exposed samples ranging from 18.2 J to 1,320 µg/kg (maximum concentration from sediments collected within RM 4 and 5; Map 5.6-6c).

One clam result was generated by exposing laboratory reared clams to Downstream Reach sediments, followed by laboratory analyses of soft body parts for PAHs. Total PAHs were detected at a concentration of 27.5 J µg/kg (Multnomah Channel; Map 5.6-6b).

Crayfish

Thirty-two whole body crayfish composites were collected within the Study Area and submitted to the laboratory for PAH analyses. PAHs were detected in eight of the samples. Total PAHs concentrations of those eight samples ranged from 1.2 J to 477 J µg/kg (RM 6 to 7; Map 5.6-7c).

Two composite whole body crayfish samples were collected from the Downstream Reach. The total PAH concentrations in these two samples were 0.99 J and 3.5 J µg/kg (between RM 1 and 1.5; Map 5.6-7a).

Two composite whole body crayfish samples were also collected from the Downtown Reach. The total PAHs concentrations in these two samples were 1.3 J and 1.7 J µg/kg (between RM 12 and 12.3; Map 5.6-7d).

Epibenthic Invertebrates

Epibenthic invertebrates (mixed taxa) collected from the Study Area were not analyzed for total PAHs.

Laboratory-Exposed *Lumbriculus* Worms

Thirty-four results were generated by exposing laboratory-reared *Lumbriculus* worms to Study Area sediments, followed by laboratory analyses of whole body worms for PAHs. PAHs were detected in each sample, with total PAHs concentrations in these laboratory-exposed samples ranging from 83 to 37,300 µg/kg (maximum concentration from sediments collected with RM 5 and 6; Map 5.6-14c).

One result was generated by exposing laboratory reared *Lumbriculus* worms to Downstream Reach sediments, followed by laboratory analyses of whole body worms for PAHs. Total PAHs concentrations were 517 µg/kg (Multnomah Channel; Map 5.6-14b).

Mussels

Seven composites of resident mussels were collected within the Study Area and submitted to the laboratory for PAH analyses. PAHs were detected in each sample, with total PAH concentrations ranging from 16 J to 150 J µg/kg (maximum concentration between RM 3 and 4; Map 5.6-9a).

5.6.6 Bis(2-ethylhexyl)phthalate in Biota

This section presents a summary of the distribution of BEHP in fish and invertebrate tissue. Scatter plots showing the distribution of BEHP concentrations in select biota tissue collected from the Study Area are provided on Figures 5.6-6a-e. A box-whisker plot showing the distribution of BEHP for each species and tissue type is provided on Figure 5.6-20.

5.6.6.1 BEHP in Fish Tissue

BEHP, the most frequently detected phthalate, was analyzed in brown bullhead, carp, Chinook salmon, lamprey, smallmouth bass, and sturgeon. Black crappie, northern pikeminnow, and peamouth were not analyzed for phthalates. The BEHP results for fish samples collected from the Study Area are shown in Table 5.6-1. Selected fish species were also collected from the Downstream, Downtown, and Upriver Reaches for BEHP analysis. A summary of the BEHP results in fish tissue collected from locations in the Downstream Reach is presented in Table 5.6-2 and from the Downtown and Upriver Reaches in Table 5.6-4. Species-specific data are summarized below by tissue type.

Black Crappie

Tissue samples of this fish species were not analyzed for BEHP.

Brown Bullhead

Brown bullhead samples were collected within the Study Area and were composited for laboratory analysis of BEHP. A total of six skin-off fillet composite samples were collected from the Study Area and submitted for laboratory analysis of BEHP. BEHP was detected in only one of six samples, with the detected concentration equaling 100 µg/kg (between RM 6 and 9; Maps 5.6-2b).

A total of six whole body composite samples were collected from the Study Area and submitted for laboratory analysis of BEHP. BEHP was detected in one of these samples at 2,700 µg/kg (between RM 3 and 6; Maps 5.6-2a).

Three whole body brown bullhead composites were also collected from the Upriver Reach, with BEHP being detected in only one of these at 3,000 J µg/kg (between RM 23 and 24; Map 5.6-15a).

Carp

Thirty-three composite samples of carp were collected from the Study Area and the Downstream Reach. These included nine body without fillet samples, nine fillet samples, six whole body samples, and nine samples based on combined fillet and body without fillet. BEHP was not detected in any of these samples.

Chinook Salmon

Eleven Chinook salmon composite samples were collected from the Study Area and four samples were collected from the Upriver Reach for analysis of BEHP. BEHP was not detected in any sample from the Study Area, but was detected in two out of four samples collected from the Upriver Reach, both at 140 J µg/kg (between RM 17 and 18; Map 5.6-16).

Lamprey Ammocoetes and Macropthalmia

One single juvenile lamprey (ammocoete) was collected within the Study Area. The BEHP concentration in the single Study Area sample equaled 170 J µg/kg (between RM 2 and 10; Map 5.6-8).

Four juvenile (ammocoetes and macropthalmia) lamprey samples (whole body composites) were collected and analyzed for BEHP. BEHP was detected in all four samples collected from the Upriver Reach, with concentrations ranging from 120 J to 160 J µg/kg(maximum concentration between RM 18 and 19; Map 5.6-16).

Largescale Sucker

Six whole body composites of largescale sucker were collected from the Study Area and submitted to the laboratory for BEHP analysis. BEHP was detected in two of six composite samples at concentrations ranging from 800 to 3,000 J µg/kg (maximum concentration between RM 7 and 9; Map 5.6-10b).

Northern Pikeminnow

Tissue samples of this fish species were not analyzed for BEHP.

Peamouth

Tissue samples of this fish species were not analyzed for BEHP.

Sculpin

Thirty-eight whole body composite samples of sculpin were collected from the Study Area and submitted to the laboratory for BEHP analysis. BEHP was detected in seven of these samples at concentrations ranging from 73 J to 28,000 J µg/kg (RM 7 to 8; Map 5.6-11d).

Two composites were collected from the Downstream Reach and two were collected from the Downtown Reach, but BEHP was not detected in any of these samples.

Smallmouth Bass

Fifty-five smallmouth bass samples were collected and submitted to the laboratory for BEHP analysis. All but 6 of these samples were collected from the Study Area. Study Area samples included 17 composites of body without fillet, 18 fillet composites, and 14 whole body composites. In addition, concentrations were derived for 17 composites by calculating concentrations for fillet and body without fillet fractions.

BEHP concentrations of these Study Area smallmouth bass samples ranged as follows:

- Fillet—BEHP detected in 3 of 18 samples, with detected concentrations ranging from 69 J to 130 J µg/kg (RM 8 to 10; Map 5.6-12d1)
- Combined fillet and body without fillet fractions—BEHP detected in 3 of 17 samples, with detected concentrations ranging from 44 J to 2,800 µg/kg (RM 11 to 12; Map 5.6-12e)
- Body without fillet—BEHP detected in 2 of 17 samples, with detected concentrations at 3,700 and 4,000 µg/kg (RM 10 to 12; Map 5.6-12e)
- Whole body—BEHP detected in 2 of 14 samples, with detected concentrations at 32,000 J and 87,000 J µg/kg (RM 3 to near 5; Map 5.6-12b).

BEHP was detected in one of six composite samples collected from the Downtown and Upriver Reaches at 4,800 µg/kg (maximum concentration between RM 20 and 25; Map 5.6-15a).

Sturgeon

Fifteen whole body composite sturgeon samples were collected from the Study Area and submitted to the laboratory for BEHP. BEHP was detected in four of these samples at concentrations ranging from 67 J to 300 µg/kg (maximum concentration between RM 7 and 8; Map 5.6-13b).

5.6.6.2 BEHP in Invertebrate Tissue

BEHP was most frequently detected in laboratory-exposed clams (82.2 percent), followed by laboratory-exposed *Lumbriculus* worms (60 percent) and field mussels (57 percent). BEHP was not detected in crayfish. Epibenthic community composites were not analyzed for phthalates. A summary of the results for BEHP in invertebrate tissue collected from the Study Area is presented in Table 5.6-5, from the Downstream Reach in Table 5.6-6, and from the Downtown and Upriver Reaches in Table 5.6-7. Taxon-specific data are summarized below.

Clams (Resident)

All clam samples consisted of soft parts only (body without shell). Thirty-seven composites of resident clams (non-depurated) were collected within the Study Area and submitted to the laboratory for BEHP analysis. BEHP was detected in six of these samples, with detected concentrations ranging from 77 J to 150 J µg/kg (maximum concentration between RM 12 and 13; Map 5.6-5f).

Two additional depurated samples were collected within the Study Area, but BEHP was not detected in those samples.

Three composite clam samples, one depurated and two not depurated, were collected from the Downstream Reach. BEHP was not detected in the non-depurated samples, and the BEHP concentration in the depurated sample was 89 J µg/kg (between RM 0 and 1.9 and Multnomah Channel; Maps 5.6-5a-b).

Three composite clam samples, one depurated and two not depurated, were also collected from the Downtown Reach. BEHP was detected in only one of the non-depurated samples at 150 J µg/kg. The BEHP concentration of the depurated sample from above the Study Area was 190 J µg/kg.

Clams (Laboratory-Exposed)

Thirty-four additional clam results were generated by exposing laboratory-reared clams to Study Area sediments, followed by analysis of soft body parts for BEHP. BEHP was detected in 26 of these samples at concentrations ranging from 53 J to 8,600 µg/kg (maximum concentration from sediments collected between RM 8 and 10; Map 5.6-6e).

One clam result was generated by exposing laboratory-reared clams to Downstream Reach sediments, followed by analysis of soft body parts for BEHP. The BEHP concentration was 120 J µg/kg (Multnomah Channel; Map 5.6-6b).

Crayfish

BEHP was not detected in any crayfish samples.

Epibenthic Invertebrates

Epibenthic invertebrates (mixed taxa) samples were not analyzed for BEHP.

Laboratory-Exposed *Lumbriculus* Worms

Thirty-four results were generated by exposing laboratory reared *Lumbriculus* worms to Study Area sediments, followed by analysis of whole body worms for BEHP. BEHP was detected in 19 of these samples, with concentrations ranging from 69 J to 220 J µg/kg (maximum concentration between RM 4 and 5; Map 5.6-14c).

One result was generated by exposing laboratory reared *Lumbriculus* worms to Downstream Reach sediments, followed by analysis of whole body worms for BEHP. BEHP was detected at a concentration of 130 J µg/kg (Multnomah Channel; Map 5.6-14b).

Mussels

Seven composites of resident mussels were collected within the Study Area and submitted to the laboratory for BEHP analysis. BEHP was detected in four of these samples at concentrations ranging from 54 J to 120 J µg/kg (maximum concentration between RM 3 and 4; Map 5.6-9a).

5.6.7 Total Chlordanes in Biota

This section presents a summary of the distribution of total chlordanes in fish and invertebrate tissue. Scatter plots showing the distribution of total chlordane concentrations in select biota tissue collected from the Study Area are provided on Figures 5.6-7a-e. A box-whisker plot showing the distribution of total chlordanes for each species and tissue type is provided on Figure 5.6-21.

5.6.7.1 Total Chlordanes in Fish Tissue

Total chlordanes were detected with varying frequency in all species except northern pikeminnow. As shown in Table 5.6-1, total chlordanes were detected in all fish samples collected from the Study Area. Selected fish species were also collected from the Downstream Reach (Table 5.6-2) and above the Study Area (Table 5.6-4). Species-specific data are summarized below, by tissue type.

Black Crappie

Four fillet and four whole body composite black crappie samples were collected from the Study Area and submitted for laboratory analysis of total chlordanes.

Total chlordanes were detected in one of four fillet samples at 1.1 J µg/kg (between RM 3 and 6; Map 5.6-1a).

Total chlordanes were also detected in all four whole body samples, with concentrations ranging from 2.1 J to 9.2 J µg/kg (maximum concentration between RM 3 and 6; Map 5.6-1a).

Brown Bullhead

Fifteen brown bullhead composite samples were analyzed for total chlordanes, including six skin-off fillet samples and seven whole body composite samples collected from the Study Area.

Total chlordanes were detected in four of six fillet samples, with concentrations ranging from 1.2 J to 1.6 J µg/kg (maximum concentration between RM 6 and 9; Map 5.6-2b).

Total chlordanes were also detected in five of seven whole body samples collected within the Study Area, with concentrations ranging from 1.8 J to 67 µg/kg (maximum concentration between RM 3 and 6; Map 5.6-2a).

Two whole body brown bullhead composites were also collected from the Upriver Reach, with total chlordanes concentrations of 1.1 N and 3.7 J µg/kg (between RM 23 and 24; Map 5.6-15a).

Carp

Twelve skin-on fillet composite samples of carp were collected within the Study Area and submitted for laboratory analysis of total chlordanes. Total chlordanes were detected in 10 of these samples, with total chlordanes concentrations ranging from 4.3 J to 12 J µg/kg (RM 4 to 8; Map 5.6-3b).

Twelve whole body composite samples of carp were analyzed for total chlordanes. These 12 samples collected from the Study Area included 6 whole body samples and 6 samples based on combined fillet and body without fillet fractions. Total chlordanes were detected in all samples, with concentrations ranging from 3.2 J to 15.4 J µg/kg (RM 4 to 8; Map 5.6-3b).

The composite carp sample with the highest level of total chlordanes was a body-without-fillet sample associated with a total chlordanes concentration of 16.8 J µg/kg, which was also collected between RM 4 and 8.

Nine composite carp samples were collected within the Downstream Reach and submitted for analysis of total chlordanes, which were detected in each sample. Total chlordanes for three skin-on fillet composite samples ranged from 7.87 J to 11.8 J µg/kg. Total chlordanes for three body without fillet composite samples ranged from 10.9 J to 14.5 J µg/kg. Total chlordanes for three composite samples of combined fillet and body with out fillet fractions ranged from 10.2 J to 13.8 J µg/kg (between RM 0 and 1.9; Map 5.6-3a).

Chinook Salmon

Fifteen whole body Chinook salmon composite samples were collected from the Study Area and eight whole body samples were collected from the Upriver Reach. Total chlordanes were detected in 12 of 15 whole body samples collected from the Study Area with concentrations ranging from 0.59 J to 7.8 J µg/kg (maximum concentration between RM 3 and 4; Map 5.6-4a). Total chlordanes were detected in 4 of 8 whole body samples collected from the Upriver Reach with concentrations ranging from 1.2 J to 3.02 J µg/kg.

Three fillet samples were also collected from the Clackamas River Fish Hatchery, but total chlordanes were not detected in those fillet samples.

Five composites of juvenile Chinook salmon stomach contents were collected from the Study Area and submitted for total chlordanes analysis. Total chlordanes were detected in all five samples, with concentrations ranging from 1.08 J to 4.61 J µg/kg (with maximum concentration between RM 6 and 7; Map 5.6-4b).

Stomach contents of the single composite sample collected from the Upriver Reach contained 2.26 J µg/kg of total chlordanes (between RM 17 and 18; Map 5.6-16).

Lamprey Ammocoetes and Macropthalmia

Six juvenile (ammocoetes) lamprey whole body composite samples were collected within the Study Area and were composited for total chlordanes analysis. Total chlordanes were detected in each sample, with concentrations ranging from 12.5 J to 29.3 J µg/kg (maximum concentration between RM 2 and 3; Map 5.6-8).

Total chlordanes were also detected in all four samples of ammocoetes and macropthalmia lamprey collected from the Upriver Reach, and total chlordanes concentrations ranged from 8.71 J to 25.2 µg/kg (maximum concentration between RM 18 and 19, Map 5.6-16).

Largescale Sucker

Six whole body composites of largescale sucker were collected from the Study Area and submitted to the laboratory for total chlordanes analysis. Total chlordanes were detected in two of six samples at concentrations ranging from 8.6 J to 9.6 J µg/kg (maximum concentration between RM 2 and 4; Map 5.6-10a).

Northern Pikeminnow

Six whole body composites of northern pikeminnow were collected from the Study Area and submitted to the laboratory for total chlordanes analysis. Total chlordanes were not detected in any of these samples.

Peamouth

Four whole body composites of peamouth were collected from the Study Area and submitted to the laboratory for total chlordanes analysis. Total chlordanes were detected in two of these samples, with concentrations of 3.1 and 3.4 µg/kg (maximum concentration with RM 4 and 6; Map 5.6-10a).

Sculpin

Forty-two whole body composite samples of sculpin were collected and submitted to the laboratory for total chlordanes analysis. Thirty-eight of these samples were collected from the Study Area, and total chlordanes were detected in 26 of those samples at concentrations ranging from 2.5 J to 16 J µg/kg (RM 7 to 8; Map 5.6-11d).

Two whole body composites were collected from the Downstream Reach, with total chlordanes concentrations in those two samples of 5.83 J and 7.38 J µg/kg (between RM 0 and 1.9; Map 5.6-11a). Two whole body sculpin composites were also collected from the Downtown Reach, with total chlordanes concentrations of 6.28 and 8.23 µg/kg in those samples (between RM 11 and 12.3; Map 5.6-11f).

Smallmouth Bass

Sixty-one smallmouth bass samples were collected and submitted to the laboratory for total chlordanes analysis. All but 6 of these samples were collected from the Study Area. Study Area samples included 18 composites of body without fillet, 23 fillet composites, and 14 whole body composites. In addition, concentrations were derived for 18 composites by calculating concentrations for fillet and body without fillet fractions.

Total chlordanes concentrations of these Study Area smallmouth bass samples ranged as follows:

- Fillet—Total chlordanes detected in 21 of 23 samples, with concentrations ranging from 0.92 J to 4.1 J µg/kg (RM 6 to 7; Map 5.6-12c2)
- Combined fillet and body without fillet fractions—Total chlordanes detected in all 18 samples, with concentrations ranging from 7.66 J to 21.7 J µg/kg (RM 8 to 9; Map 5.6-12d2)
- Body without fillet—Total chlordanes detected in all 18 samples, with concentrations ranging from 9.57 J to 29.5 µg/kg (RM 8 to 9; Map 5.6-12d2)
- Whole body—Total chlordanes detected in 2 of 14 samples, with detected concentrations ranging from5.4 to 5.6 µg/kg (RM 6.6 to near 7.5; Map 5.6-12c2).

Total chlordanes concentrations of the six whole body composites collected from the Downtown and Upriver Reaches ranged from 4.5 J to 15 J µg/kg (maximum concentration between RM 20 and 25; Map 5.6-15a).

Sturgeon

Twenty-one sturgeon samples were collected from the Study Area and submitted to the laboratory for total chlordanes analysis. These included 5 composite skin-off fillet samples, 15 whole body samples, and 1 sample for stomach contents. Total chlordanes were detected in all samples except 1 fillet sample.

Whole body total chlordanes concentrations ranged from 6.22 J to 20.4 µg/kg (maximum concentration between RM 7 and 8; Map 5.6-13b). Total chlordanes detected concentrations in skin-off fillet samples ranged from 2.5 J to 5.6 J µg/kg (maximum concentration between RM 6 and 7; Map 5.6-13a).

The total chlordanes concentration of the single stomach contents sample equaled 0.914 J µg/kg (between RM 7 and 8; Map 5.6-13b).

5.6.7.2 Total Chlordanes in Invertebrate Tissue

Total chlordanes were detected in all invertebrate samples collected from the Study Area except 22 crayfish tissues, as shown in Table 5.6-5. Selected invertebrate species were also collected from the Downstream Reach (Table 5.6-6) and from the Downtown and Upriver Reaches (Table 5.6-7). Taxon-specific data are summarized below.

Clams (Resident)

All clam samples consisted of composites of soft parts only (body without shell). Forty-four composites of resident clams (non-depurated) were collected within the Study Area and submitted to the laboratory for total chlordanes analysis. Total chlordanes were detected in all samples, with concentrations ranging from 1.1 NJ to 16 J µg/kg (maximum concentration between RM 8 and 9; Map 5.6-5e).

Five additional depurated samples were collected within the Study Area, with total chlordanes concentrations ranging from 1.35 J to 3.11 J µg/kg (maximum concentration between RM 2 and 3; Map 5.6-5b).

Three composite clam samples, one depurated and two not depurated, were collected from the Downstream Reach. The total chlordanes concentrations in the non-depurated samples were 2.41 J and 3.02 J µg/kg, while the total chlordanes concentration of the depurated sample was 2.46 J µg/kg (between RM 0 and 1.9 and Multnomah Channel; Maps 5.6-5a-b).

Three composite clam samples, one depurated and two not depurated, were also collected from the Downtown Reach. The total chlordanes concentrations in the non-depurated samples were 1.99 J and 2.52 J µg/kg (between RM 11.9 and RM 12.3; Map 5.6-5f). The total chlordanes concentration of the depurated sample from above the Study Area was 1.9 J µg/kg (near RM 12.3; Map 5.6-5f).

Clams (Laboratory-Exposed)

Thirty-four additional clam results were generated by exposing laboratory-reared clams to Study Area sediments, followed by analysis of soft body parts for total chlordanes. Total chlordanes were detected in all samples. The total chlordanes concentrations of these 45 laboratory-exposed samples ranged from 1.61 J to 8.2 J µg/kg (maximum concentration from sediments collected between RM 6 and 7; Map 5.6-6d).

One clam result was generated by exposing laboratory-reared clams to Downstream Reach sediments, followed by analysis of soft body parts for total chlordanes. Total chlordanes were detected at a concentration of 1.92 J µg/kg (Multnomah Channel; Map 5.6-6b).

Crayfish

Thirty-two whole body crayfish composites were collected within the Study Area and submitted to the laboratory for chlordane analysis. Total chlordanes were not detected in 22 of these samples. Total detected chlordanes concentrations in those samples ranged from 0.164 J to 2.7 NJ µg/kg (RM 4 to 5; Map 5.6-7b).

Two composite whole body crayfish samples were collected from the Downstream Reach. The total chlordanes concentrations in these two samples were 0.20 J and 0.207J µg/kg (between RM 1 and 1.5; Map 5.6-7a).

Two composite whole body crayfish samples were also collected from the Downtown Reach. The total chlordanes concentrations in these two samples were 0.226 J and 0.382 J µg/kg (near RM 12; Map 5.6-7d).

Epibenthic Invertebrates

Seven composite samples of epibenthic invertebrates (mixed taxa) were collected from the Study Area and analyzed for total chlordanes, with detected concentrations in all samples ranging from 0.313 J to 2.06 J µg/kg (maximum concentration between RM 6 and 7; Map 5.6-9a).

Laboratory-Exposed *Lumbriculus* Worms

Thirty-four results were generated by exposing laboratory-reared *Lumbriculus* worms to Study Area sediments, followed by analysis of whole body worms for total chlordanes. Total chlordanes were detected in all samples, with concentrations ranging from 1.89 J to 71.9 µg/kg (maximum concentration between RM 8 and 9; Map 5.6-14e).

One result was generated by exposing laboratory-reared *Lumbriculus* worms to Downstream Reach sediments, followed by analysis of whole body worms for total chlordanes. Total chlordanes were detected at a concentration of 1.89 J µg/kg (Multnomah Channel; Map 5.6-14b).

Mussels

Seven composites of resident mussels were collected within the Study Area and submitted to the laboratory for total chlordanes analysis. Total chlordanes were detected in all samples with concentrations ranging from 0.191 J to 0.866 J µg/kg (maximum concentration between RM 8 and 9; Map 5.6-9b).

5.6.8 Aldrin in Biota

This section presents a summary of the distribution of aldrin in fish and invertebrate tissue. Scatter plots showing the distribution of aldrin concentrations in select biota tissue collected from the Study Area are provided on Figures 5.6-8a-e. A box-whisker plot showing the distribution of aldrin for each species and tissue type is provided on Figure 5.6-22.

5.6.8.1 Aldrin in Fish Tissue

Aldrin was only detected in juvenile lamprey, Chinook salmon (stomach contents only), carp, smallmouth bass, sturgeon, and sculpin. Laboratory detection limits were lower for Round 2 and Round 3 samples than for Round 1 samples. Study Area data are summarized in Table 5.6-1. Tables 5.6-2 and 5.6-4 present data for samples collected below and above the Study Area, respectively. Species-specific data are summarized below by tissue type.

Black Crappie

Aldrin was not detected in any black crappie samples.

Brown Bullhead

Aldrin was not detected in any brown bullhead samples.

Carp

Twelve skin-on fillet composite samples of carp were collected within the Study Area and submitted for laboratory analysis of aldrin. Aldrin was detected in six of these samples, with concentrations ranging from 0.0541 J to 0.119 J µg/kg (RM 4 to 8; Map 5.6-3b).

Aldrin was not detected in the six whole body carp samples analyzed for aldrin. In contrast, aldrin was detected in all six body without fillet samples and in all six combined fillet and body without fillet samples. Aldrin concentrations in these samples ranged from 0.0839 J to 0.185 J µg/kg (RM 8 to 12; Map 5.6-3c) and from 0.0755 J to 0.163 µg/kg (RM 8 to 12; Map 5.6-3c), respectively.

Nine composite carp samples were collected within the Downstream Reach (between RM 0 and 1; Map 5.6-3a) and submitted for analysis of aldrin, which was detected in each sample. Aldrin concentrations for three skin-on fillet composite samples ranged from 0.046 J to 0.079 J µg/kg. Aldrin concentrations for three body without fillet composite samples ranged from 0.0634 J to 0.125 J µg/kg. Aldrin concentrations for three composite samples of combined fillet and body without fillet fractions ranged from 0.059 J to 0.11 J µg/kg.

Chinook Salmon

Fifteen juvenile Chinook salmon whole body composite samples were collected within the Study Area and eight whole body composite samples were collected from the Upriver Reach and submitted to the laboratory for aldrin analysis. Aldrin was not detected in any of these samples or any of the fillet samples from the Clackamas River Fish Hatchery.

Aldrin was detected in two out of five juvenile Chinook salmon stomach contents samples collected from the Study Area. Aldrin concentrations in these samples ranged from 0.00576 J to 0.0426 J µg/kg (maximum concentration between RM 6 and 7; Map 5.6-4b).

Lamprey Ammocoetes and Macropthalmia

Six whole body juvenile (ammocoetes and macropthalmia) lamprey samples were collected within the Study Area and were composited for aldrin analysis. Aldrin was detected in all six samples, with concentrations ranging from 0.874 to 1.82 µg/kg (ammocoete; maximum concentration between RM 2 and 3; Map 5.6-8). Aldrin was also detected in all four of the composite samples collected from the Upriver Reach, at concentrations ranging from 0.65 to 2.72 µg/kg (maximum concentration between RM 18 and 19; Map 5.6-16).

Largescale Sucker

Aldrin was not detected in any largescale sucker samples.

Northern Pikeminnow

Northern pikeminnow samples were not analyzed for aldrin.

Peamouth

Peamouth samples were not analyzed for aldrin.

Sculpin

Forty-two whole body composite samples of sculpin were collected and submitted to the laboratory for aldrin analysis. Aldrin was detected in 10 of the 38 samples collected from the Study Area, with concentrations ranging from 0.00532 to 0.0348 µg/kg (RM 8 to 9; Map 5.6-11e).

Two composites were collected from the Downstream Reach, with aldrin being detected in only one of those samples at 0.00814 µg/kg (between RM 1 and 2; Map 5.6-11a). One whole body sculpin composite was also collected from the Downtown Reach, at a detected aldrin concentration of 0.0101 µg/kg (near RM 11.8; Map 5.6-11f).

Smallmouth Bass

Sixty-one smallmouth bass samples were collected and submitted to the laboratory for aldrin analysis. All but 6 of these samples were collected from the Study Area. Study Area samples included 18 composites of body without fillet, 23 fillet composites, and 14 whole body composites. In addition, concentrations were derived for 18 composites by calculating concentrations for fillet and body without fillet fractions.

Aldrin concentrations of these Study Area smallmouth bass samples ranged as follows:

- Fillet—Aldrin was detected in 6 of 23 samples at concentrations ranging from 0.005 J to 0.011 J µg/kg (RM 8 to 9; Map 5.6-12d2)
- Combined fillet and body without fillet fractions—Aldrin was detected in 15 of 18 samples at concentrations ranging from 0.0104 J to 0.04 J µg/kg (RM 8 to 9; Map 5.6-12d2)
- Body without fillet—Aldrin was detected in 13 of 18 samples at concentrations ranging from 0.0104 J to 0.0566 J µg/kg (RM 8 to 10; Map 5.6-12d1)
- Whole body—Aldrin was not detected in the 14 samples analyzed for aldrin.

Aldrin was also not detected in the six whole body composites collected from the Downtown and Upriver Reaches.

Sturgeon

Twenty-one sturgeon samples were collected from the Study Area and submitted to the laboratory for aldrin analysis. These included 5 composite skin-off fillet samples, 15 whole body samples, and 1 sample for stomach contents.

Aldrin was not detected in the fillet samples nor was it detected in 2 of the 15 whole body samples. Whole body detected concentrations ranged from 0.0103 J to 0.0554 J µg/kg (maximum concentration between RM 2 and 3; Map 5.6-13a).

The aldrin concentration of the single stomach contents sample equaled 0.00442 J µg/kg (between RM 7 and 8; Map 5.6-13b).

5.6.8.2 Aldrin in Invertebrate Tissue

Aldrin was detected in all sampled invertebrate species collected within the Study Area (Table 5.6-5). Selected invertebrate species were also collected from the Downstream Reach and from the Downtown and Upriver Reaches (Tables 5.6-6 and 5.6-7, respectively). Taxon-specific data are summarized below.

Clams (Resident)

All clam samples consisted of composites of soft parts only (body without shell). Forty composites of resident clams (non-depurated) were collected within the Study Area and submitted to the laboratory for aldrin analysis. Aldrin was detected in 36 of these samples, with concentrations ranging from 0.126 J to 5.07 µg/kg (maximum concentration between RM 9 and 10; Map 5.6-5e).

Three additional depurated samples were collected within the Study Area, and aldrin was detected in two of these samples at concentrations of 0.173 J and 0.278 J µg/kg (maximum concentration between RM 2 and 3; Map 5.6-5b).

Three composite clam samples, one depurated and two not depurated, were collected from the Downstream Reach. Aldrin was detected in both samples, with the concentrations in the non-depurated samples equaling 0.144 J and 0.23 J µg/kg (between RM 0 and 1.9 and Multnomah Channel: Maps 5.6-5a-b). The aldrin concentration of the depurated sample equaled 0.187 J µg/kg (near RM 1.6; Map 5.6-5a).

Three composite clam samples, one depurated and two not depurated, were also collected from the Downtown Reach. The aldrin concentrations in the two non-depurated samples were 0.11 J and 0.13 J µg/kg (between RM 11.9 and 12.3; Map 5.6-5f). Aldrin was not detected in the depurated sample from the downtown reach.

Clams (Laboratory-Exposed)

Thirty-five additional clam results were generated by exposing laboratory-reared clams to Study Area sediments, followed by analysis of soft body parts for aldrin. Aldrin was detected in 28 of these samples, with concentrations ranging from 0.0119 J to 2.14 µg/kg (maximum concentration from sediments collected between RM 8 and 9; Map 5.6-6e).

One clam result was generated by exposing laboratory-reared clams to Downstream Reach sediments, followed by analysis of soft body parts for aldrin. Aldrin was detected at a concentration of 0.0118 J µg/kg (Multnomah Channel; Map 5.6-6b).

Crayfish

Thirty-two whole body crayfish composites were collected within the Study Area and submitted to the laboratory for aldrin. Aldrin was detected in one of the samples at 0.037 J µg/kg (RM 8 to 9; Map 5.6-7c).

Aldrin was not detected in the two composite whole body crayfish samples collected from the Downstream Reach, nor was it detected in the two composite whole body crayfish samples collected from the Downtown Reach.

Epibenthic Invertebrates

Seven composite samples of epibenthic invertebrates (mixed taxa) were collected from the Study Area and analyzed for aldrin. Aldrin was detected in six of those samples at concentrations ranging from 0.00926 J to 0.0872 µg/kg (maximum concentration between RM 9 and 10; Map 5.6-9b).

Laboratory-Exposed *Lumbriculus* Worms

Thirty-four results were generated by exposing laboratory reared *Lumbriculus* worms to Study Area sediments, followed by analysis of whole body worms for aldrin. Aldrin was detected in 34 of 35 samples, with concentrations ranging from 0.043 J to 37 µg/kg (maximum concentration between RM 8 and 9; Map 5.6-14e).

One result was generated by exposing laboratory-reared *Lumbriculus* worms to Downstream Reach sediments, followed by analysis of whole body worms for aldrin. Aldrin was detected at a concentration of 0.073 J µg/kg (Multnomah Channel; Map 5.6-14b).

Mussels

Seven composites of resident mussels were collected within the Study Area and submitted to the laboratory for aldrin analysis. Aldrin was detected in four of these samples at concentrations ranging from 0.007 J to 0.067 J µg/kg (maximum concentration between RM 8 and 9; Map 5.6-9b).

5.6.9 Dieldrin in Biota

This section presents a summary of the distribution of dieldrin in fish and invertebrate tissue. Scatter plots showing the distribution of dieldrin concentrations in select biota tissue collected from the Study Area are provided on Figures 5.6-9a-e. A box-whisker plot showing the distribution of dieldrin for each species and tissue type is provided on Figure 5.6-23.

5.6.9.1 Dieldrin in Fish Tissue

Dieldrin was detected in all sampled fish species, except largescale sucker, northern pikeminnow, and peamouth. Study Area data are summarized in Table 5.6-1. Data on samples collected from the Downstream and Downtown Reaches are shown in Tables 5.6-2 and 5.6-4, respectively. Species-specific data are summarized below, by tissue type.

Black Crappie

Dieldrin was detected in one of four whole body black crappie composite samples collected within the Study Area, with a detected concentration of 2.5 J µg/kg (between RM 6 and 9; Map 5.6-1b). Dieldrin was not detected in any of the four composites of fillet samples collected from the Study Area.

Brown Bullhead

Dieldrin was detected in one of six skin-off fillet composite samples collected within the Study Area, at a concentration of 2.1 J µg/kg (between RM 3 and 6; Map 5.6-2a). Dieldrin was also detected in two of six whole body composite samples collected within the Study Area, with concentrations ranging from 1.2 J to 2.6 J µg/kg (maximum concentration between RM 3 and 6; Map 5.6-2a).

Dieldrin was detected in one of two whole body composite samples collected from the Upriver Reach, with concentrations in both samples equaling 1.2 J µg/kg (between RM 23 and 24 and at RM 28; Maps 5.6-15a-b).

Carp

Twelve skin-on fillet composite samples of carp were collected within the Study Area and submitted for laboratory analysis of dieldrin. Dieldrin was detected in six of these samples, with concentrations ranging from 1.29 to 2.3 µg/kg (maximum concentration between RM 4 and 8; Map 5.6-3b).

Dieldrin was not detected in the six whole body carp samples collected from the Study Area. In contrast, dieldrin was detected all six body without fillet samples and in all six combined fillet and body without fillet samples. Dieldrin concentrations in these samples ranged from 2.14 to 3.22 µg/kg (RM 5 to 8; Map 5.6-3b) and from1.9 to 3 µg/kg (RM 4 to 8; Map 5.6-3b), respectively.

Nine composite carp samples were collected within the Downstream Reach (between RM 0 and 1.9; Map 5.6-3a) and submitted for analysis of dieldrin, which was detected in each sample. Dieldrin concentrations for three skin-on fillet composite samples ranged from 1.66 to 2.03 µg/kg. Dieldrin concentrations for three body without fillet composite samples ranged from 2.24 to 2.95 µg/kg. Dieldrin concentrations for three composite samples of combined fillet and body without fillet fractions ranged from 2.1 to 2.72 µg/kg.

Chinook Salmon

Fifteen juvenile Chinook salmon whole body composite samples were collected from the Study Area and three whole body composite samples were collected from the upriver reach of the Study Area and submitted to the laboratory for dieldrin analysis. No fillet samples were collected within the Study Area, but three fillet composites were collected from the Upriver Reach.

Dieldrin was detected in one of three fillet composites from the Clackamas River Fish Hatchery at 2 J µg/kg.

Dieldrin was detected in 6 out of 15 whole body composites from the Study Area and ranged from 0.23 J to 2.6 µg/kg (maximum concentration between RM 3 and 4; Map 5.6-4a). Detected concentrations of dieldrin in 7 of 8 whole body composites collected from the Clackamas River Fish Hatchery ranged from 0.65 J µg/kg to 1.6 µg/kg (between RM 17 and RM 18; Map 5.6-16).

Five Chinook salmon stomach contents samples collected from the Study Area contained dieldrin at concentrations ranging from 0.471 J to 2.92 µg/kg (maximum concentration between RM 7 and 8; Map 5.6-4b). The dieldrin concentration in the single stomach contents sample collected from the Upriver Reach equaled 0.905 µg/kg (Table 5.6-4).

Lamprey Ammocoetes and Macropthalmia

Six whole body juvenile (ammocoetes and macropthalmia) lamprey samples were collected within the Study Area and were composited for dieldrin analysis. Dieldrin was detected in all six samples, with concentrations in macropthalmia ranging from 0.89 to 6.38 µg/kg (maximum concentration between RM 2 and 9; Map 5.6-8). Dieldrin was also detected in all four of the macropthalmia lamprey composite samples collected from the Upriver Reach, at concentrations ranging from 0.698 to 5.36 µg/kg (maximum concentration between RM 18 and 19; Map 5.6-16).

Largescale Sucker

Dieldrin was not detected in any largescale sucker samples.

Northern Pikeminnow

Dieldrin was not detected in any northern pikeminnow samples.

Peamouth

Dieldrin was not detected in any peamouth samples.

Sculpin

Forty-two whole body composite samples of sculpin were collected and submitted to the laboratory for dieldrin analysis. Dieldrin was detected in 26 of the 38 samples collected from the Study Area, with concentrations ranging from 0.867 J to 24 J µg/kg (RM 2 to 3; Map 5.6-11b).

Two composites were collected from the Downstream Reach, with dieldrin being detected in both samples at concentrations of 0.89 J and 1.47 µg/kg (between RM 1 and 1.9; Map 5.5-11a). Dieldrin was also detected in both samples collected from the Downtown Reach at concentrations of 1.11 and 1.26 µg/kg (between RM 11.8 and 12.3; Map 5.6-11f).

Smallmouth Bass

Sixty-one smallmouth bass samples were collected and submitted to the laboratory for dieldrin analysis. All but 6 of these samples were collected from the Study Area. Study Area samples included 18 composites of body without fillet, 23 fillet composites, and 14 whole body composites. In addition, concentrations were derived for 18 composites by calculating concentrations for fillet and body without fillet fractions.

Dieldrin concentrations of these Study Area smallmouth bass samples ranged as follows:

- Fillet—Dieldrin was detected in 21 of 23 samples at concentrations ranging from 0.183 to 3.3 J µg/kg (RM 2 to 4; Map 5.6-12a)
- Combined fillet and body without fillet fractions—Dieldrin was detected in all 18 samples at concentrations ranging from 1.38 to 2.94 µg/kg (RM 8 to 10; Map 5.6-12d1)
- Body without fillet—Dieldrin was detected in all 18 samples at concentrations ranging from 1.76 to 4.17 µg/kg (RM 8 to 10; Map 5.6-12d1)
- Whole body—Dieldrin was detected in 1 of 14 samples analyzed for dieldrin at 7.3 J µg/kg (RM 7 to 8; Map 5.6-12d2).

Dieldrin was detected in the six whole body composites collected from the Downtown and Upriver Reaches at concentrations ranging from 1.9 J to 4.5 J µg/kg (maximum concentration between RM 20 and 25; Map 5.6-15a).

Sturgeon

Twenty-one sturgeon samples were collected from the Study Area and submitted to the laboratory for dieldrin analysis. These included 5 composite skin-off fillet samples, 15 whole body samples, and 1 sample for stomach contents.

Dieldrin was detected in two of five fillet samples collected from the Study Area at concentrations ranging from 0.67 J to 1.4 J µg/kg (maximum concentration between RM 6 and 7; Map 5.6-13a).

Dieldrin was detected in all 15 whole body samples at concentrations ranging from 1.24 to 3.11 µg/kg (maximum concentration between RM 7 and 8; Map 5.6-13b).

The dieldrin concentration of the single stomach contents sample collected from the Study Area equaled 0.359 µg/kg (between RM 7 and 8; Map 5.6-13b).

5.6.9.2 Dieldrin in Invertebrate Tissue

Dieldrin was detected in all sampled invertebrate species and in most but not all samples. Selected invertebrate species were collected from within the Study Area (Table 5.6-5), and some samples were also collected from the Downstream Reach (Table 5.6-6) and the Downtown and Upriver Reaches (Table 5.6-7). Taxon-specific data are summarized below.

Clams (Resident)

All clam samples consisted of composites of soft parts only (body without shell). Forty composites of resident clams (non-depurated) were collected within the Study Area and submitted to the laboratory for dieldrin analysis. Dieldrin was detected in 37 of these samples, with concentrations ranging from 0.338 J to 2.62 µg/kg (RM 8 to 9; Map 5.6-5e).

Three additional depurated samples were collected within the Study Area, and dieldrin was detected in all of these samples at concentrations ranging from 0.339 J to 0.593 J µg/kg (RM 2 to 3; Map 5.6-5b).

Three composite clam samples, one depurated and two not depurated, were collected from the Downstream Reach. Dieldrin was detected in both samples, with the concentrations in the non-depurated samples equaling 0.591 J and 0.609 µg/kg (near RM 1.6 and Multnomah Channel; Maps 5.6-5a-b). The dieldrin concentration of the depurated sample equaled 0.504 J µg/kg (near RM 1.6; Map 5.6-5a).

Three composite clam samples, one depurated and two not depurated, were also collected from the Downtown Reach. The dieldrin concentrations in the two non-depurated samples were 0.495 J and 0.61 J µg/kg (between RM 11.8 and 12.3; Map 5.6-5f). The dieldrin concentration of the depurated sample from above the Downtown Reach was 0.425 J µg/kg (near RM 11.8; Map 5.6-5f).

Clams (Laboratory-Exposed)

Thirty-four additional clam results were generated by exposing laboratory-reared clams to Study Area sediments, followed by analysis of soft body parts for dieldrin. Dieldrin was detected in all of these samples, with concentrations ranging from 0.139 J to

4.14 µg/kg (maximum concentration from sediments collected between RM 8 and 9; Map 5.6-6e).

One clam result was generated by exposing laboratory-reared clams to Downstream Reach sediments, followed by analysis of soft body parts for dieldrin. Dieldrin was detected at a concentration of 0.155 J µg/kg (Multnomah Channel; Map 5.6-6b).

Crayfish

Thirty-two whole body crayfish composites were collected within the Study Area and submitted to the laboratory for dieldrin. Dieldrin was detected in 5 of 32 samples at concentrations ranging from 0.00943 J to 0.0471 J µg/kg (maximum concentration between RM 8 to 9; Map 5.6-7c).

Dieldrin was detected in one of two composite whole body crayfish samples collected from the Downstream Reach at 0.0134 J µg/kg (near RM 1.4; Map 5.6-7a). Dieldrin was also detected in the two composite whole body crayfish samples collected from the Downtown Reach at concentrations of 0.0105 J and 0.0164 J µg/kg (between RM 12 and 12.3; Map 5.6-7d).

Epibenthic Invertebrates

Seven composite samples of epibenthic invertebrates (mixed taxa) were collected from the Study Area and analyzed for dieldrin. Dieldrin was detected in all of those samples at concentrations ranging from 0.098 to 0.396 µg/kg (maximum concentration between RM 6 and 7; Map 5.6-9a).

Laboratory-Exposed *Lumbriculus* Worms

Thirty-four results were generated by exposing laboratory-reared *Lumbriculus* worms to Study Area sediments, followed by analysis of whole body worms for dieldrin. Dieldrin was detected in all samples, with concentrations ranging from 0.127 J to 26.7 µg/kg (maximum concentration between RM 8 and 9; Map 5.6-14e).

One result was generated by exposing laboratory-reared *Lumbriculus* worms to Downstream Reach sediments, followed by analysis of whole body worms for dieldrin. Dieldrin was detected at a concentration of 0.499 µg/kg (Multnomah Channel; Map 5.6-14b).

Mussels

Seven composites of resident mussels were collected within the Study Area and submitted to the laboratory for dieldrin analysis. Dieldrin was detected in all of these samples at concentrations ranging from 0.0742 J to 0.186 J µg/kg (maximum concentration between RM 8 and 9; Map 5.6-9b).

5.6.10 Arsenic in Biota

This section presents a summary of the distribution of arsenic in fish and invertebrate tissue. Scatter plots showing the distribution of arsenic concentrations in select biota tissue collected from the Study Area are provided on Figures 5.6-10a-e. A box-whisker plot showing the distribution of arsenic concentrations in whole body tissue samples collected of each species across the Study Area is provided on Figure 5.6-24.

5.6.10.1 Arsenic in Fish Tissue

Arsenic was detected in all fish tissue types collected from the Study Area (Table 5.6-1) that were analyzed for this contaminant. Selected fish species were also collected from the Downstream Reach (Table 5.6-2) and the Downtown and Upriver Reaches (Table 5.6-4) for arsenic analysis. Species-specific data are summarized below by tissue type.

Black Crappie

Individual black crappie samples were collected over a 6-mile reach of the river within the Study Area and were composited for laboratory analysis. A total of four fillet (with skin) composite samples were submitted for laboratory analysis of arsenic. Arsenic was detected in all four samples, with concentrations ranging from 0.1 J to 0.18 mg/kg (maximum concentration between RM 6 and 9; Map 5.6-1b).

A total of four whole body composite samples were submitted for laboratory analysis of arsenic. Arsenic was detected in all four samples, with concentrations ranging from 0.185 to 0.42 mg/kg (maximum concentration within RM 6 and 9; Map 5.6-1b).

Brown Bullhead

Brown bullhead samples were collected over an approximately 6-mile reach of the river within the Study Area and were composited for laboratory analysis. A total of six skin-off fillet composite samples were submitted for laboratory analysis of arsenic. Arsenic was detected in all six samples, with a concentration of 0.02 J mg/kg in each sample (between RM 3 and 9; Maps 5.6-2a-b).

A total of six whole body composite samples collected from the Study Area were submitted for laboratory analysis of arsenic. Arsenic was detected in all six samples, with concentrations ranging from 0.04 J to 0.08 J mg/kg (maximum concentration between RM 6 and 9; Map 5.6-2b).

Three whole body brown bullhead samples were collected from the Upriver Reach. Arsenic was detected in each sample, with concentrations ranging from 0.07 J to 0.09 J mg/kg (between RM 23 and 24; Map 5.6-15a).

Carp

Twelve skin-on fillet composite samples of carp were collected within the Study Area and submitted for laboratory analysis of arsenic. Arsenic was detected in each sample, with concentrations ranging from 0.04 J to 0.160 mg/kg (RM 0 to 4; Map 5.6-3a).

Six whole body composite carp samples were submitted for arsenic analysis, which was detected in each sample at concentrations ranging from 0.125 J to 0.22 mg/kg (maximum concentration between RM 0 and 4; Map 5.6-3a). Six whole body composite samples of carp based on combined fillet and body without fillet fractions were also submitted for laboratory analysis of arsenic. Arsenic was detected in each sample, with concentrations ranging from 0.034 J to 0.12 J mg/kg (between RM 0 and 4; Map 5.6-3a). Additionally, six carp body without fillet samples were collected from the Study Area. Arsenic was detected in five of the samples, with concentrations ranging from 0.086 J to 0.136 J mg/kg (between RM 0 and 4; Map 5.6-3a).

Nine composite carp samples were collected within the Downstream Reach (between RM 0 and 1; Map 5.6-3a) and submitted for analysis of arsenic, which was detected in each sample. Arsenic concentrations for three skin-on fillet composite samples ranged from 0.06 J to 0.21 mg/kg. Arsenic concentrations for three body without fillet composite samples ranged from 0.088 J to 0.234 mg/kg. Arsenic concentrations for three composite samples of combined fillet and body without fillet fractions ranged from 0.081 J to 0.23 mg/kg.

Chinook Salmon

Fifteen juvenile whole body Chinook salmon samples were collected within the Study Area and were composited for laboratory analysis of arsenic. Arsenic was detected in each sample, with concentrations ranging from 0.0465 to 0.25 mg/kg (maximum concentration between RM 3 and 4; Map 5.6-4a).

Eight whole body composite samples were also collected from the Clackamas River Fish Hatchery for arsenic analysis. Arsenic was detected in each sample, with concentrations ranging from 0.03 J to 0.979 mg/kg.

Three fillet composite samples were collected from the Clackamas River Fish Hatchery and submitted for laboratory analysis of arsenic. Arsenic was detected in each sample, with concentrations ranging from 0.72 to 1.26 mg/kg.

Lamprey Ammocoetes and Macropthalmia

Four juvenile (ammocoetes and macropthalmia) lamprey samples were collected from the Study Area for arsenic analysis. Arsenic was detected in each sample, with concentrations ranging from 0.05 J to 0.19 mg/kg (maximum concentration between RM 1 and 10; Map 5.6-8).

Four juvenile lamprey samples were also collected from the Upriver Reach for arsenic analysis. Arsenic was detected in each sample, with concentrations in macropthalmia ranging from 0.08 J to 0.19 mg/kg (maximum concentration between RM 18 and 19; Map 5.6-16).

Largescale Sucker

Six whole body composites of largescale sucker were collected from the Study Area and submitted to the laboratory for arsenic analysis. Arsenic was detected in each sample, with concentrations ranging from 0.18 to 0.27 mg/kg (maximum concentration between RM 2 and 4; Map 5.6-10a).

Northern Pikeminnow

Six whole body composites of northern pikeminnow were collected from the Study Area and submitted to the laboratory for arsenic analysis. Arsenic concentrations were detected in these six samples and concentrations ranged from 0.19 to 0.36 mg/kg (maximum concentration between RM 2 and 4; Map 5.6-10a).

Peamouth

Four whole body composites of peamouth were collected from the Study Area and submitted to the laboratory for arsenic analysis. Arsenic concentrations in these samples ranged from 0.35 to 0.48 mg/kg (maximum concentration with RM 8 and 10; Map 5.6-10b).

Sculpin

Forty-two whole body composite samples of sculpin were collected and submitted to the laboratory for arsenic analysis. Thirty-eight of these samples were collected from the Study Area. Arsenic was detected in each of the samples collected from the Study Area, with concentrations ranging from 0.13 to 0.35 mg/kg (RM 10 to 11; Map 5.6-11f).

Two whole body composites were collected from the Downstream Reach, with a detected concentration of 0.33 mg/kg in both samples (between RM 1 and 1.9; Map 5.6-11a). Two whole body sculpin composites were also collected from the Downtown Reach for arsenic analysis, which was detected at a concentration of 0.2mg/kg in both samples (between RM 11.8 and 12.3; Map 5.6-11f).

Smallmouth Bass

Sixty-one smallmouth bass samples were collected and submitted to the laboratory for arsenic analysis. All but 6 of these samples were collected from the Study Area. Study Area samples included 18 composites of body without fillet, 23 fillet composites, and 14 whole body composites. In addition, concentrations were derived for 18 composites by calculating concentrations for fillet and body without fillet fractions.

Arsenic was detected in all of the samples collected from the Study Area. Detected concentrations in these Study Area smallmouth bass samples, as presented on Maps 5.6-12a-e, ranged as follows:

- Fillet—0.14 to 0.34 mg/kg (RM 2 to 3)
- Combined fillet and body without fillet fractions—0.16 to 0.36 mg/kg (RM 2 to 5)
- Body without fillet—0.17 to 0.38 mg/kg (RM 2 to 5)
- Whole body—0.17 to 0.39 mg/kg (RM 2 to 5).

Arsenic was detected in the six whole body samples collected from the Downtown and Upriver Reaches, with concentrations ranging from 0.1 J to 0.36 mg/kg (maximum concentration between RM 20 and 25; Map 5.6-15a).

Sturgeon

Twenty-three sturgeon samples were collected from the Study Area and submitted to the laboratory for arsenic analysis. These included 5 composite skin-off fillet samples, 15 whole body samples, and 3 samples of stomach contents.

As presented on Maps 5.6-13a-b, arsenic was detected in all of the samples. Detected arsenic concentrations of skin-off fillet samples ranged from 0.157 to 0.538 mg/kg (maximum concentration between RM 5 and 6). Whole body arsenic concentrations ranged from 0.298 to 1.06 mg/kg (maximum concentration between RM 6 and 7). The arsenic concentrations in the three stomach contents samples ranged from 0.17 to 0.82 mg/kg (maximum concentration between RM 6 and 7).

5.6.10.2 Arsenic in Invertebrate Tissue

As shown in Table 5.6-5, arsenic was detected in all invertebrate species and tissue types collected from the Study Area for which arsenic analysis was conducted. Selected invertebrate species were also collected from the Downstream Reach and from the Downtown and Upriver Reaches (Tables 5.6-6 and 5.6-7, respectively). Taxon-specific data are summarized below.

Clams (Resident)

All clam samples consisted of soft parts only (body without shell). Thirty-seven composite samples of resident clams (non-depurated) were collected within the Study Area and submitted to the laboratory for arsenic analysis. Arsenic was detected in all of the samples, with concentrations ranging from 0.654 to 1.25 mg/kg (RM 2 to 3; Map 5.6-5b). Three additional depurated samples were collected within the Study Area for arsenic analysis. Arsenic was detected in each sample, with concentrations ranging from 0.798 to 1.35 mg/kg (RM 2 to 3; Map 5.6-5b).

Three composite clam samples, one depurated and two not depurated, were collected from the Downstream Reach. Arsenic was detected in the depurated sample at a concentration of 1.02 mg/kg and in the non-depurated samples at concentrations of 1.03 and 1.07 mg/kg (between RM 0 and 1.9 and Multnomah Channel; Maps 5.6-5a-b).

Three composite clam samples, one depurated and two not depurated, were also collected from the Downtown Reach. Arsenic was detected in the depurated sample at a concentration of 0.76 mg/kg and in the non-depurated samples at concentrations of 0.615 and 0.799 mg/kg (between RM 11.9 and 12.3; Map 5.6-5f).

Clams (Laboratory-Exposed)

Thirty four additional clam results were generated by exposing laboratory-reared clams to Study Area sediments, followed by analysis of soft body parts for arsenic. Arsenic was detected in all of the samples, with concentrations ranging from 0.303 J to 0.548 mg/kg (maximum concentration from sediments collected between RM 8 and 9; Map 5.6-6e).

One clam result was generated by exposing laboratory-reared clams to Downstream Reach sediments, followed by analysis of soft body parts for arsenic. Arsenic was detected at a concentration of 0.411 mg/kg (Multnomah Channel; Map 5.6-6b).

Crayfish

Thirty-two whole body crayfish composites were collected within the Study Area and submitted to the laboratory for arsenic analysis. Arsenic was detected in all but one of the samples, with concentrations ranging from 0.235 to 0.5 J mg/kg (RM 7 to 8; Map 5.6-7c).

Two composite whole body crayfish samples were collected from the Downstream Reach. Arsenic was detected at concentrations of 0.34 and 0.4 mg/kg (between RM 1 and 1.5; Map 5.6-7a).

Two composite whole body crayfish samples were also collected from the Downtown Reach. Arsenic was detected at a concentration of 0.29 mg/kg in both samples (between RM 12 and 12.3; Map 5.6-7d).

Epibenthic Invertebrates

Two composite samples of epibenthic invertebrates (mixed taxa) were collected from the Study Area and analyzed for arsenic, with detected concentrations of 0.349 and 0.45 mg/kg (between RM 2 and 3; Map 5.6-9a).

Laboratory-Exposed *Lumbriculus* Worms

Thirty-four results were generated by exposing laboratory-reared *Lumbriculus* worms to Study Area sediments, followed by analysis of whole body worms for arsenic. Arsenic was detected in all of the samples, with concentrations in these laboratory-exposed samples ranging from 0.285 to 3.04 mg/kg (maximum concentration from sediments collected between RM 7 and 8; Map 5.6-14d).

One result was generated by exposing laboratory-reared *Lumbriculus* worms to Downstream Reach sediments, followed by analysis of whole body worms for arsenic. Arsenic was detected at a concentration of 0.469 mg/kg (Multnomah Channel; Map 5.6-14b).

Mussels

Seven composites of resident mussels were collected within the Study Area and submitted to the laboratory for arsenic analysis. Arsenic was detected in each sample, with concentrations ranging from 0.224 to 0.616 mg/kg (maximum concentration between RM 7 and 8; Map 5.6-9b).

5.6.11 Chromium in Biota

This section presents a summary of the distribution of chromium in fish and invertebrate tissue. Scatter plots showing the distribution of chromium concentrations in select biota tissue collected from the Study Area are provided on Figures 5.6-11a-e. A box-whisker plot showing the distribution of chromium concentrations in whole body tissue samples collected of each species across the Study Area is provided on Figure 5.6-25.

5.6.11.1 Chromium in Fish Tissue

Chromium was detected in all fish samples collected from the Study Area that were analyzed for this contaminant, with the exception of whole body black crappie samples (Table 5.6-1). Selected fish species were also collected from the Downstream Reach (Table 5.6-2) and the Downtown and Upriver Reaches (Table 5.6-4) for chromium analysis. Species-specific data are summarized below by tissue type.

Black Crappie

Individual black crappie samples were collected over a 6-mile reach of the river within the Study Area and were composited for laboratory analysis. A total of four fillet (with skin) composite samples were submitted for laboratory analysis of chromium. Chromium was detected in two of the four samples, with concentrations of 0.14 and 0.28 mg/kg (maximum concentration between RM 3 and 6; Map 5.6-1a).

A total of four whole body composite samples were submitted for laboratory analysis of chromium. Chromium was not detected above laboratory reporting limits in any of the samples.

Brown Bullhead

Brown bullhead samples were collected over an approximately 6-mile reach of the river within the Study Area and were composited for laboratory analysis. A total of six skin-off fillet composite samples were submitted for laboratory analysis of chromium. Chromium was detected in three of the samples, with concentrations ranging from 0.05 J to 0.23 mg/kg (maximum concentration between RM 3 and 6; Map 5.6-2a).

A total of six whole body composite samples collected from the Study Area were submitted for laboratory analysis of chromium. Chromium was detected in all six samples, with concentrations ranging from 0.39 to 1.32 mg/kg (maximum concentration between RM 3 and 6; Map 5.6-2a).

Three whole body brown bullhead samples were collected from the Upriver Reach. Chromium was detected in each sample, with concentrations ranging from 0.485 to 2.04 mg/kg (maximum concentration between RM 28 and 33; Map 5.6-15b).

Carp

Twelve skin-on fillet composite samples of carp were collected within the Study Area and submitted for laboratory analysis of chromium. Chromium was detected in four of the samples, with concentrations ranging from 0.12 J to 1.49 mg/kg (maximum concentration between RM 3 and 6; Maps 5.6-3a-b).

Six whole body composite carp samples were submitted for chromium analysis, which was detected in each sample at concentrations ranging from 0.305 to 2.02 mg/kg (maximum concentration between RM 3 and 6; Maps 5.6-3a-b). Six whole body composite samples of carp based on combined fillet and body without fillet fractions were also submitted for laboratory analysis of chromium. Chromium was detected in each sample, with concentrations ranging from 0.23 to 0.8 mg/kg (between RM 0 to 4; Map 5.6-3a). Additionally, six carp body without fillet samples were collected from the Study Area. Chromium was detected in each sample, with concentrations ranging from 0.3 to 1.09 mg/kg (RM 0 to 4; Map 5.6-3a).

Nine composite carp samples were collected within the Downstream Reach (between RM 0 and 1; Map 5.6-3a) and submitted for analysis of chromium, which was detected in six of nine samples. Chromium was not detected for the skin-on fillet composite samples. Chromium concentrations for three body without fillet composite samples ranged from 0.47 to 1.91 mg/kg. Chromium concentrations for three composite samples of combined fillet and body without fillet fractions ranged from 0.36 to 1.5 mg/kg.

Chinook Salmon

Fifteen juvenile whole body Chinook salmon samples were collected within the Study Area and were composited for laboratory analysis of chromium. Chromium was detected in three of the samples, with concentrations ranging from 0.09 J to 0.19 mg/kg (maximum concentration between RM 2 and 3; Map 5.6-4a).

Eight juvenile whole body composite samples were also collected from the Clackamas River Fish Hatchery for chromium analysis. Chromium was detected in four of the samples, with concentrations ranging from 0.182 to 0.402 mg/kg.

Three fillet composite samples were collected from the Clackamas River Fish Hatchery and submitted for laboratory analysis of chromium. Chromium was detected in each sample, with concentrations ranging from 0.282 to 0.33 mg/kg.

Lamprey Ammocoetes and Macropthalmia

Four juvenile (ammocoetes and macropthalmia) lamprey samples were collected from the Study Area for chromium analysis. Chromium was detected in each sample, with concentrations ranging from 0.13 J to 0.32 mg/kg (ammocoetes; maximum concentration between RM 1 and 10; Map 5.6-8).

Four juvenile lamprey samples were also collected from the Upriver Reach for chromium analysis. Chromium was detected in 3 of the samples, with concentrations in macropthalmia ranging from 0.256 to 0.3 mg/kg (maximum concentration between RM 18 and 19; Map 5.6-16).

Largescale Sucker

Six whole body composites of largescale sucker were collected from the Study Area and submitted to the laboratory for chromium analysis. Chromium was detected in each sample, with concentrations ranging from 0.38 to 2.77 mg/kg (maximum concentration between RM 7 and 9; Map 5.6-10a).

Northern Pikeminnow

Six whole body composites of northern pikeminnow were collected from the Study Area and submitted to the laboratory for chromium analysis. Chromium was detected in five samples, with concentrations ranging from 0.09 J to 0.67 mg/kg (maximum concentration between RM 6 and 8; Map 5.6-10a).

Peamouth

Four whole body composites of peamouth were collected from the Study Area and submitted to the laboratory for chromium analysis. Chromium was detected in three samples, with concentrations ranging from 0.2 to 0.49 mg/kg (maximum concentration between RM 2 and 4; Map 5.6-10a).

Sculpin

Forty-two whole body composite samples of sculpin were collected and submitted to the laboratory for chromium analysis. Thirty-eight of these samples were collected from the Study Area. Chromium was detected in 22 of the samples collected from the Study Area, with concentrations ranging from 0.1 J to 0.6 mg/kg (RM 9 to 10; Map 5.6-11e).

Two whole body composites were collected from the Downstream Reach, with detected concentrations of 0.2 J mg/kg and 0.4 mg/kg (near RM 1.5; Map 5.6-11a). Two whole body sculpin composites were also collected from the Downtown Reach for chromium analysis, which was detected at concentrations of 0.15 J mg/kg and 0.3mg/kg (between RM 11.8 and 12.3; Map 5.6-11f).

Smallmouth Bass

Sixty-one smallmouth bass samples were collected and submitted to the laboratory for chromium analysis. All but 6 of these samples were collected from the Study Area. Study Area samples included 18 composites of body without fillet, 23 fillet composites, and 14 whole body composite samples. In addition, concentrations were derived for 18 composites by calculating concentrations for fillet and body without fillet fractions.

Chromium was detected in 8 composites of body without fillet, 9 composites of combined fillet and body without fillet fractions, 2 fillet composites, and 12 whole body composite samples collected from the Study Area. Detected chromium concentrations in these Study Area smallmouth bass samples, as presented on Maps 5.6-12a-e, ranged as follows:

- Fillet—0.2 J to 0.9 mg/kg (RM 8 to 9)
- Combined fillet and body without fillet fractions—0.13 J to 0.4 J mg/kg (RM 8 to 9)
- Body without fillet—0.2 J mg/kg in each sample (RM 8 to 10)
- Whole body—0.17 to 1.14 mg/kg (RM 8 to 10).

Chromium was detected in the six whole body samples collected from above the Downtown and Upriver Reaches, with concentrations ranging from 0.16 to 2.79 mg/kg (maximum concentration between RM 20 and 25; Map 5.6-15a).

Sturgeon

Twenty-three sturgeon samples were collected from the Study Area and submitted to the laboratory for chromium analysis. These included 5 composite skin-off fillet samples, 15 whole body samples, and 3 samples of stomach contents.

As presented on Maps 5.6-13a-b, chromium was detected in all of the fillet and stomach content samples, but only in two of the whole body samples. Detected chromium concentrations of skin-off fillet samples ranged from 0.412 to 3.25 mg/kg (maximum concentration between RM 5 and 6). Whole body chromium concentrations were 0.2 J and 40.2 mg/kg (maximum concentration between RM 2 and 3). The chromium concentrations in the three stomach contents samples ranged from 0.15 J to 4.1 mg/kg (maximum concentration between RM 6 and 7).

5.6.11.2 Chromium in Invertebrate Tissue

As shown in Table 5.6-5, chromium was detected in all invertebrate species and tissue types collected from the Study Area for which chromium analysis was conducted. Selected invertebrate species were also collected from the Downstream Reach and from the Downtown and Upriver Reaches (Tables 5.6-6 and 5.6-7, respectively). Taxon-specific data are summarized below.

Clams (Resident)

All clam samples consisted of soft parts only (body without shell). Thirty-eight composite samples of resident clams (non-depurated) were collected within the Study Area and submitted to the laboratory for chromium analysis. Chromium was detected in all of the samples, with concentrations ranging from 0.4 to 1.05 mg/kg (RM 3 to 4; Map 5.6-5b). Three additional depurated samples were collected within the Study Area for chromium analysis. Chromium was detected in each sample, with concentrations ranging from 0.4 to 0.5 mg/kg (RM 2 to 3 and RM 11 to 12; Maps 5.6-5b and f).

Three composite clam samples, one depurated and two not depurated, were collected from the Downstream Reach. Chromium was detected in the depurated sample at a concentration of 0.4 mg/kg and in the non-depurated samples at concentrations of 0.5 and 0.62 mg/kg (between RM 0 and 1.9 and Multnomah Channel; Maps 5.6-5a-b).

Three composite clam samples, one depurated and two not depurated, were also collected from the Downtown Reach. Chromium was detected in the depurated sample at a concentration of 0.5 mg/kg and in the non-depurated samples at concentrations of 0.5 and 0.7 mg/kg (between RM 11.8 and RM 12.3; Map 5.6-5f).

Clams (Laboratory-Exposed)

Thirty-four additional clam results were generated by exposing laboratory-reared clams to Study Area sediments, followed by analysis of soft body parts for chromium. Chromium was detected in all of the samples, with concentrations ranging from 0.14 to 0.49 mg/kg (maximum concentration from sediments collected between RM 9 and 10; Map 5.6-6e).

One clam result was generated by exposing laboratory-reared clams to Downstream Reach sediments, followed by analysis of soft body parts for chromium. Chromium was detected at a concentration of 0.17 mg/kg (Multnomah Channel; Map 5.6-6b).

Crayfish

Thirty-two whole body crayfish composites were collected within the Study Area and submitted to the laboratory for chromium analysis. Chromium was detected in all of the samples, with concentrations ranging from 0.09 J to 0.9 mg/kg (RM 6 to 7; Map 5.6-7c).

Two composite whole body crayfish samples were collected from the Downstream Reach. Chromium was detected at concentrations of 0.2 J and 0.4 mg/kg (between RM 1 and 1.5; Map 5.6-7a).

Two composite whole body crayfish samples were also collected from the Downtown Reach. Chromium was detected at concentrations of 0.3 J and 0.4 mg/kg (between RM 12 and 12.3; Map 5.6-7d).

Epibenthic Invertebrates

Two composite samples of epibenthic invertebrates (mixed taxa) were collected from the Study Area and analyzed for chromium, with detected concentrations of 0.64 and 1.73 mg/kg (between RM 9 and 10; Map 5.6-9b).

Laboratory-Exposed *Lumbriculus* Worms

Thirty-four results were generated by exposing laboratory-reared *Lumbriculus* worms to Study Area sediments, followed by analysis of whole body worms for chromium. Chromium was detected in all of the samples, with concentrations in these laboratory exposed samples ranging from 0.14 to 0.89 mg/kg (maximum concentration from sediments collected between RM 8 and 9; Map 5.6-14e).

One result was generated by exposing laboratory-reared *Lumbriculus* worms to Downstream Reach sediments, followed by analysis of whole body worms for chromium. Chromium was detected at a concentration of 0.35 mg/kg (Multnomah Channel; Map 5.6-14b).

Mussels

Seven composites of resident mussels were collected within the Study Area and submitted to the laboratory for chromium analysis. Chromium was detected in three samples, with concentrations ranging from 0.21 to 0.28 mg/kg (maximum concentration between RM 3 and 4; Map 5.6-9a).

5.6.12 Copper in Biota

This section presents a summary of the distribution of copper in fish and invertebrate tissue. Scatter plots showing the distribution of copper concentrations in select biota tissue collected from the Study Area are provided on Figures 5.6-12a-e. A box-whisker plot showing the distribution of copper concentrations in whole body tissue samples collected of each species across the Study Area is provided on Figure 5.6-26.

5.6.12.1 Copper in Fish Tissue

Copper was detected in all fish samples collected from the Study Area that were analyzed for this contaminant (Table 5.6-1). Selected fish species were also collected from the Downstream Reach (Table 5.6-2) and the Downtown and Upriver Reaches (Table 5.6-4) for copper analysis. Species-specific data are summarized below by tissue type.

Black Crappie

Individual black crappie samples were collected over a 6-mile reach of the river within the Study Area and were composited for laboratory analysis. A total of four fillet (with skin) composite samples were submitted for laboratory analysis of copper. Copper was detected in all four samples, with concentrations ranging from 0.166 to 0.184 mg/kg (maximum concentration between RM 3 and 6; Map 5.6-1a).

A total of four whole body composite samples were submitted for laboratory analysis of copper. Copper was detected in all four samples, with concentrations ranging from 0.688 to 0.946 mg/kg (maximum concentration between RM 3 and 6; Map 5.6-1a).

Brown Bullhead

Brown bullhead samples were collected over an approximately 6-mile reach of the river within the Study Area and were composited for laboratory analysis. A total of six skin-off fillet composite samples were submitted for laboratory analysis of copper. Copper was detected in all six samples, with concentrations ranging from 0.203 to 0.292 mg/kg (maximum concentration between RM 3 and 6; Map 5.6-2a).

A total of six whole body composite samples collected from the Study Area were submitted for laboratory analysis of copper. Copper was detected in all six samples, with concentrations ranging from 0.586 to 0.798 mg/kg (maximum concentration between RM 6 and 9; Map 5.6-2b).

Three whole body brown bullhead samples were collected from the Upriver Reach. Copper was detected in each sample, with concentrations ranging from 0.625 to 0.89 mg/kg (maximum concentration between RM 28 and 33; Map 5.6-15b).

Carp

Twelve skin-on fillet composite samples of carp were collected within the Study Area and submitted for laboratory analysis of copper. Copper was detected in each sample, with concentrations ranging from 0.313 to 0.566 mg/kg (RM 0 to 4; Map 5.6-3a).

Six whole body composite carp samples were submitted for copper analysis, which was detected in each sample at concentrations ranging from1.04 to 1.42 mg/kg (maximum concentration between RM 0 and 6; Maps 5.6-3a-b). Six whole body composite samples of carp based on combined fillet and body without fillet fractions were also submitted for laboratory analysis of copper. Copper was detected in each sample, with concentrations ranging from 0.897 to 1.23 mg/kg (between RM 0 to 4; Map 5.6-3a). Additionally, six carp body without fillet samples were collected from the Study Area. Copper was detected in each sample, with concentrations ranging from 1.02 to 1.53 mg/kg (RM 3 to 4; Map 5.6-3a).

Nine composite carp samples were collected within the Downstream Reach (between RM 0 and 1; Map 5.6-3a) and submitted for analysis of copper, which was detected in all nine samples. Copper concentrations for the skin-on fillet composite samples ranged from 0.476 to 0.686 mg/kg. Copper concentrations for three body without fillet composite samples ranged from 1.07 to 1.67 mg/kg. Copper concentrations for three composite samples of combined fillet and body without fillet fractions ranged from 0.92 to 1.42 mg/kg.

Chinook Salmon

Fifteen juvenile whole body Chinook salmon samples were collected within the Study Area and were composited for laboratory analysis of copper. Copper was detected in each sample, with concentrations ranging from 0.755 to 2.15 mg/kg (maximum concentration between RM 2 and 3; Map 5.6-4a).

Eight juvenile whole body composite samples were also collected from the Clackamas River Fish Hatchery for copper analysis. Copper was detected in each sample, with concentrations ranging from 0.879 to 1.5 mg/kg (between RM 17 and 18; Map 5.6-16).

Three fillet composite samples were collected from the Clackamas River Fish Hatchery and submitted for laboratory analysis of copper. Copper was detected in each sample, with concentrations ranging from 0.507 to 0.532 mg/kg.

Lamprey Ammocoetes and Macropthalmia

Four juvenile (ammocoetes and macropthalmia) lamprey samples were collected from the Study Area for copper analysis. Copper was detected in each sample, with concentrations in macropthalmia ranging from 3.08 to 6.2 mg/kg (maximum concentration with RM 1 and 9; Map 5.6-8).

Four juvenile lamprey samples were also collected from the Upriver Reach for copper analysis. Copper was detected in each sample, with concentrations in macropthalmia ranging from 3.92 to 4.8 mg/kg (maximum concentration between RM 18 and 19; Map 5.6-16).

Largescale Sucker

Six whole body composites of largescale sucker were collected from the Study Area and submitted to the laboratory for copper analysis. Copper was detected in each sample, with concentrations ranging from 0.735 to 1.1 mg/kg (maximum concentration between RM 7 and 9; Map 5.6-10b).

Northern Pikeminnow

Six whole body composites of northern pikeminnow were collected from the Study Area and submitted to the laboratory for copper analysis. Copper was detected in all six samples and concentrations ranged from 0.575 to 0.89 mg/kg (maximum concentration between RM 8 and 10; Map 5.6-10b).

Peamouth

Four whole body composites of peamouth were collected from the Study Area and submitted to the laboratory for copper analysis. Copper was detected in all four samples and concentrations ranged from 0.73 to 1.61 mg/kg (maximum concentration between RM 2 and 4; Map 5.6-10a).

Sculpin

Forty-two whole body composite samples of sculpin were collected and submitted to the laboratory for copper analysis. Thirty-eight of these samples were collected from the Study Area. Copper was detected in each of the samples collected from the Study Area, with concentrations ranging from 0.929 to 7.16 mg/kg (RM 10 to 11; Map 5.6-11f).

Two whole body composites were collected from the Downstream Reach, with detected concentrations of 1.25 and 3.77 mg/kg (near RM 1.5; Map 5.6-11a). Two whole body sculpin composites were also collected from the Downtown Reach for copper analysis, which was detected at concentrations of 0.856 and 2.98 mg/kg (between RM 11.8 and 12.3; Map 5.6-11f).

Smallmouth Bass

Sixty-one smallmouth bass samples were collected and submitted to the laboratory for copper analysis. All but 6 of these samples were collected from the Study Area. Study

Area samples included 18 composites of body without fillet, 23 fillet composites, and 14 whole body composites. In addition, concentrations were derived for 18 composites by calculating concentrations for fillet and body without fillet fractions.

Copper was detected in all of the samples collected from the Study Area. Detected copper concentrations of these Study Area smallmouth bass samples, as presented on Maps 5.6-12a-e, ranged as follows:

- Fillet—0.187 to 1.12 mg/kg (RM 5 to 6)
- Combined fillet and body without fillet fractions—0.444 to 1.92 mg/kg (RM 10 to 11)
- Body without fillet—0.464 to 2.59 mg/kg (RM 10 to 11)
- Whole body—0.365 to 1.29 mg/kg (RM 7 to 9).

Copper was detected in the six whole body samples collected from the Downtown and Upriver Reaches, with concentrations ranging from 0.37 to 0.54 mg/kg (maximum concentration between RM 20 and 25; Map 5.6-15a).

Sturgeon

Twenty-three sturgeon samples were collected from the Study Area and submitted to the laboratory for copper analysis. These included 5 composite skin-off fillet samples, 15 whole body samples, and 3 samples of stomach contents.

As presented on Maps 5.6-13a-b, copper was detected in all of the samples. Detected copper concentrations of skin-off fillet samples ranged from 0.127 to 0.253 mg/kg (maximum concentration between RM 5 and 6). Whole body copper concentrations ranged from 0.544 to 0.959 mg/kg (maximum concentration between RM 2 and 3). The copper concentrations in the three stomach contents samples ranged from 6.73 J to 11 J mg/kg (maximum concentration between RM 2 and 3).

5.6.12.2 Copper in Invertebrate Tissue

As shown in Table 5.6-5, copper was detected in all invertebrate species and tissue types collected from the Study Area for which copper analysis was conducted. Selected invertebrate species were also collected from the Downstream Reach and from the Downtown and Upriver Reaches (Tables 5.6-6 and 5.6-7, respectively). Taxon-specific data are summarized below.

Clams (Resident)

All clam samples consisted of composites of soft parts only (body without shell). Thirty-seven composite samples of resident clams (non-depurated) were collected within the Study Area and submitted to the laboratory for copper analysis. Copper was detected in all of the samples, with concentrations ranging from 5.99 to 13.5 mg/kg (RM 8 to 9; Map 5.6-5e). Three additional depurated samples were collected within the

Study Area for copper analysis. Copper was detected in each sample, with concentrations ranging from 6.85 to 9.03 mg/kg (RM 9 to 10; Map 5.6-5e).

Three composite clam samples, one depurated and two not depurated, were collected from the Downstream Reach. Copper was detected in the depurated sample at a concentration of 7.59 mg/kg and in the non-depurated samples at concentrations of 8.23 and 9.35 mg/kg (RM 1.6 and Multnomah Channel; Maps 5.6-5a-b).

Three composite clam samples, one depurated and two not depurated, were also collected from the Downtown Reach. Copper was detected in the depurated sample at a concentration of 7.62 mg/kg and in the non-depurated samples at concentrations of 4.57 and 6.97 mg/kg (between RM 11.9 and 12.3; Map 5.6-5f).

Clams (Laboratory-Exposed)

Thirty-four additional clam results were generated by exposing laboratory-reared clams to Study Area sediments, followed by analysis of soft body parts for copper. Copper was detected in all of the samples, with concentrations ranging from 2.64 to 5.94 J mg/kg (maximum concentration from sediments collected between RM 8 and 9; Map 5.6-6e).

One clam result was generated by exposing laboratory reared clams to Downstream Reach sediments, followed by analysis of soft body parts for copper. Copper was detected at a concentration of 3.67 J mg/kg (Multnomah Channel; Map 5.6-6b).

Crayfish

Thirty-two whole body crayfish composites were collected within the Study Area and submitted to the laboratory for copper analysis. Copper was detected in all of the samples, with concentrations ranging from 10.4 to 20.2 mg/kg (RM 11 to 12; Map 5.6-7d).

Two composite whole body crayfish samples were collected from the Downstream Reach. Copper was detected at concentrations of 14.3 and 15.5 mg/kg (between RM 1 and 1.5; Map 5.6-7a).

Two composite whole body crayfish samples were also collected from the Downtown Reach. Copper was detected at concentrations of 17 and 18 mg/kg (between RM 12 and 12.3; Map 5.6-7d).

Epibenthic Invertebrates

Two composite samples of epibenthic invertebrates (mixed taxa) were collected from the Study Area and analyzed for copper, with detected concentrations of 3.01 J and 6 J mg/kg (between RM 2 and 3; Map 5.6-9a).

Laboratory-Exposed *Lumbriculus* Worms

Thirty-four results were generated by exposing laboratory-reared *Lumbriculus* worms to Study Area sediments, followed by analysis of whole body worms for copper. Copper was detected in all of the samples, with concentrations in these laboratory-exposed samples ranging from 1.83 to 20.2 mg/kg (maximum concentration from sediments collected between RM 8 and 9; Map 5.6-14e).

One result was generated by exposing laboratory-reared *Lumbriculus* worms to Downstream Reach sediments, followed by analysis of whole body worms for copper. Copper was detected at a concentration of 2.88 mg/kg (Multnomah Channel; Map 5.6-14b).

Mussels

Seven composites of resident mussels were collected within the Study Area and submitted to the laboratory for copper analysis. Copper was detected in each sample, with concentrations ranging from 1.01 to 1.82 mg/kg (maximum concentration between RM 3 and 4; Map 5.6-9a).

5.6.13 Zinc in Biota

This section presents a summary of the distribution of zinc in fish and invertebrate tissue. Scatter plots showing the distribution of zinc concentrations in select biota tissue collected from the Study Area are provided on Figures 5.6-13a-e. A box-whisker plot showing the distribution of zinc concentrations in whole body tissue samples collected of each species across the Study Area is provided on Figure 5.6-27.

5.6.13.1 Zinc in Fish Tissue

Zinc was detected in all fish samples collected from the Study Area that were analyzed for this contaminant (Table 5.6-1). Selected fish species were also collected from the Downstream Reach (Table 5.6-2) and the Downtown and Upriver Reaches (Table 5.6-4) for zinc analysis. Species-specific data are summarized below by tissue type.

Black Crappie

Individual black crappie samples were collected within the Study Area and were composited for laboratory analysis. A total of four fillet (with skin) composite samples were submitted for laboratory analysis of zinc. Zinc was detected in all four samples, with concentrations ranging from 7.45 to 9.03 mg/kg (maximum concentration between RM 3 and 6; Map 5.6-1a).

A total of four whole body composite samples were submitted for laboratory analysis of zinc. Zinc was detected in all four samples, with concentrations ranging from 14.2 to 16.8 mg/kg (maximum concentration between RM 6 and 9; Map 5.6-1b).

Brown Bullhead

Brown bullhead samples were collected within the Study Area and were composited for laboratory analysis. A total of six skin-off fillet composite samples were submitted for laboratory analysis of zinc. Zinc was detected in all six samples, with concentrations ranging from 3.96 J to 6.49 J mg/kg (maximum concentration between RM 3 and 6; Map 5.6-2a).

A total of six whole body composite samples were submitted for laboratory analysis of zinc. Zinc was detected in all six samples, with concentrations ranging from 12.7 to 15.6 mg/kg (maximum concentration between RM 6 and 9; Map 5.6-2b).

Two whole body brown bullhead samples were collected from the Upriver Reach. Zinc was detected in each sample, with concentrations ranging from 13.9 to 14.45 mg/kg (maximum concentration between RM 28 and 33; Map 5.6-15b).

Carp

Twelve skin-on fillet composite samples of carp were collected within the Study Area and submitted for laboratory analysis of zinc. Zinc was detected in each sample, with concentrations ranging from 17.4 J to 31 mg/kg (maximum concentration between RM 4 and 8; Map 5.6-3b).

Six whole body composite carp samples were submitted for zinc analysis, which was detected in each sample at concentrations ranging from 87.1 to 112 mg/kg (maximum concentration between RM 4 and 8; Map 5.6-3b). Six whole body composite samples of carp based on combined fillet and body without fillet fractions were also submitted for laboratory analysis of zinc. Zinc was detected in each sample, with concentrations ranging from 71.2 to 113 mg/kg (maximum concentration between RM 4 and 8; Map 5.6-3b). Additionally, six carp body without fillet samples were collected from the Study Area. Zinc was detected in each sample, with concentrations ranging from 89.9 to 147 mg/kg (maximum concentration between RM 4 and 8; Map 5.6-3b).

Nine composite carp samples were collected within the Downstream Reach (between RM 0 and 1; Map 5.6-3a) and submitted for analysis of zinc, which was detected in all nine samples. Zinc concentrations for the skin-on fillet composite samples ranged from 24.8 to 30.6 mg/kg. Zinc concentrations for three body without fillet composite samples ranged from 88 to 111 mg/kg. Zinc concentrations for three composite samples of combined fillet and body without fillet fractions ranged from 72 to 89.9 mg/kg.

Chinook Salmon

Fifteen juvenile whole body Chinook salmon samples were collected within the Study Area and were composited for laboratory analysis of zinc. Zinc was detected in each sample, with concentrations ranging from 24 to 33.3 mg/kg (maximum concentration between RM 2 and 3; Map 5.6-4a).

Eight juvenile whole body composite samples were also collected from the Clackamas River Fish Hatchery for zinc analysis. Zinc was detected in each sample, with concentrations ranging from 22 to 37.5 mg/kg (between RM 17 and 18; Map 5.6-16).

Three fillet composite samples were collected from the Clackamas River Fish Hatchery and submitted for laboratory analysis of zinc. Zinc was detected in each sample, with concentrations ranging from 4.56 to 4.6 mg/kg.

Lamprey Ammocoetes and Macropthalmia

Four juvenile (ammocoetes and macropthalmia) lamprey samples were collected from the Study Area for zinc analysis. Zinc was detected in each sample, with concentrations in ammocoete ranging from 19 to 26.7 mg/kg (maximum concentration with RM 10 and 11.8; Map 5.6-8).

Four juvenile lamprey samples were also collected from the Upriver Reach for zinc analysis. Zinc was detected in each sample, with concentrations in macropthalmia ranging from 25.8 to 29.1 mg/kg (maximum concentration between RM 18 and 19; Map 5.6-16).

Largescale Sucker

Six whole body composites of largescale sucker were collected from the Study Area and submitted to the laboratory for zinc analysis. Zinc was detected in each sample, with concentrations ranging from 17.1 to 19.7 mg/kg (maximum concentration between RM 7 and 9; Map 5.6-10a).

Northern Pikeminnow

Six whole body composites of northern pikeminnow were collected from the Study Area and submitted to the laboratory for zinc analysis. Zinc was detected in all six samples, with concentrations ranging from 16.4 to 20 mg/kg (maximum concentration between RM 8 and 10; Map 5.6-10b).

Peamouth

Four whole body composites of peamouth were collected from the Study Area and submitted to the laboratory for zinc analysis. Zinc was detected in all four samples, with concentrations ranging from 23.1 to 25.2 mg/kg (maximum concentration between RM 8 and 10; Map 5.6-10b).

Sculpin

Forty-two whole body composite samples of sculpin were collected and submitted to the laboratory for zinc analysis. Thirty-eight of these samples were collected from the Study Area. Zinc was detected in each of the samples collected from the Study Area, with concentrations ranging from 11.7 to 18 mg/kg (maximum concentration between RM 4 and 5; Map 5.6-11c).

Two whole body composites were collected from the Downstream Reach, with detected concentrations of 13.1 and 16.8 mg/kg (near RM 1.5; Map 5.6-11a). Two whole body sculpin composites were also collected from the Downtown Reach for zinc analysis, which was detected at concentrations of 15 and 15.3 mg/kg (between RM 11.8 and 12.3; Map 5.6-11f).

Smallmouth Bass

Sixty-one smallmouth bass samples were collected and submitted to the laboratory for zinc analysis. All but 6 of these samples were collected from the Study Area. Study Area samples included 18 composites of body without fillet, 23 fillet composites, and 14 whole body composites. In addition, concentrations were derived for 18 composites by calculating concentrations for fillet and body without fillet fractions.

Zinc was detected in all of the samples collected from the Study Area. Detected zinc concentrations of these Study Area smallmouth bass samples, as presented on Maps 5.6-12a-e, ranged as follows:

- Fillet—7.12 to 10.9 J mg/kg (RM 5 to 6)
- Combined fillet and body without fillet fractions—10.8 to 13 mg/kg (RM 6 to 8)
- Body without fillet—11.5 to 15 mg/kg (RM 8 to 9)
- Whole body—13.4 to 16.3 mg/kg (RM 2 to 5).

Zinc was detected in the six whole body samples collected from above the Downtown and Upstream Reaches, with concentrations ranging from 12.8 to 16.8 mg/kg (maximum concentration between RM 28 and 33, Map 5.6-15b).

Sturgeon

Twenty-three sturgeon samples were collected from the Study Area and submitted to the laboratory for zinc analysis. These included 5 composite skin-off fillet samples, 15 whole body samples, and 3 samples of stomach contents.

As presented on Maps 5.6-13a-b, zinc was detected in all of the samples. Detected zinc concentrations of skin-off fillet samples ranged from 2.08 to 2.93 mg/kg (maximum concentration between RM 5 and 6). Whole body zinc concentrations ranged from 7.39 to 11.9 mg/kg (maximum concentration between RM 3 and 5). The zinc concentrations in the three stomach contents samples ranged from 9.56 to 19.1 mg/kg (maximum concentration between RM 2 and 3).

5.6.13.2 Zinc in Invertebrate Tissue

As shown in Table 5.6-5, zinc was detected in all invertebrate species and tissue types collected from the Study Area for which zinc analysis was conducted. Selected invertebrate species were also collected from the Downstream Reach and from the Downtown and Upriver Reaches (Tables 5.6-6 and 5.6-7, respectively). Taxon-specific data are summarized below.

Clams (Resident)

All clam samples consisted of soft parts only (body without shell). Thirty-seven composite samples of resident clams (non-depurated) were collected within the Study Area and submitted to the laboratory for zinc analysis. Zinc was detected in all of the samples, with concentrations ranging from 19.6 to 54 mg/kg (RM 8 to 9; Map 5.6-5e). Three additional depurated samples were collected within the Study Area for zinc analysis. Zinc was detected in each sample, with concentrations ranging from 19.3 to 27.9 mg/kg (RM 10 to 11; Map 5.6-5f).

Three composite clam samples, one depurated and two not depurated, were collected from the Downstream Reach. Zinc was detected in the depurated sample at a concentration of 21.3 mg/kg (near RM 1.6; Map 5.6-5a) and in the non-depurated samples at concentrations of 25.4 and 30.5 mg/kg (near RM 1.6 and Multnomah Channel; Maps 5.6-5a-b).

Three composite clam samples, one depurated and two not depurated, were also collected from the Downtown Reach. Zinc was detected in the depurated sample at a concentration of 23.7 mg/kg and in the non-depurated samples at concentrations of 27.8 and 30.4 mg/kg (between RM 11.9 and 12.3; Map 5.6-5f).

Clams (Laboratory-Exposed)

Thirty-four additional clam results were generated by exposing laboratory-reared clams to Study Area sediments, followed by analysis of soft body parts for zinc. Zinc was detected in all of the samples, with concentrations ranging from 10.8 to 16.8 mg/kg (maximum concentration from sediments collected between RM 8 and 9; Map 5.6-6e).

One clam result was generated by exposing laboratory-reared clams to Downstream Reach sediments, followed by analysis of soft body parts for zinc. Zinc was detected at a concentration of 12.2 mg/kg (Multnomah Channel; Map 5.6-6b).

Crayfish

Thirty-two whole body crayfish composites were collected within the Study Area and submitted to the laboratory for zinc analysis. Zinc was detected in all of the samples, with concentrations ranging from 13.7 J to 20.3 J mg/kg (RM 6 to 7; Map 5.6-7c).

Two composite whole body crayfish samples were collected from the Downstream Reach. Zinc was detected at concentrations of 15.3 and 15.9 mg/kg (between RM 1 and 1.5; Map 5.6-7a).

Two composite whole body crayfish samples were also collected from the Downtown Reach. Zinc was detected at concentrations of 18.9 and 19.4 mg/kg (between RM 12 and 12.3; Map 5.6-7d).

Epibenthic Invertebrates

Two composite samples of epibenthic invertebrates (mixed taxa) were collected from the Study Area and analyzed for zinc, with detected concentrations of 12.6 J and 24.8 J mg/kg (between RM 9 and 10; Map 5.6-9b).

Laboratory-Exposed *Lumbriculus* Worms

Thirty-four results were generated by exposing laboratory-reared *Lumbriculus* worms to Study Area sediments, followed by analysis of whole body worms for zinc. Zinc was detected in all of the samples, with concentrations in these laboratory exposed samples ranging from 18.2 to 31.5 mg/kg (maximum concentration from sediments collected between RM 4 and 5; Map 5.6-14b).

One result was generated by exposing laboratory reared *Lumbriculus* worms to Downstream Reach sediments, followed by analysis of whole body worms for zinc. Zinc was detected at a concentration of 26.1 mg/kg (Multnomah Channel; Map 5.6-14b).

Mussels

Seven composites of resident mussels were collected within the Study Area and submitted to the laboratory for zinc analysis. Zinc was detected in each sample, with concentrations ranging from 15.7 to 41.5 mg/kg (maximum concentration between RM 7 and 8; Map 5.6-9b).

5.6.14 Tributyltin Ion in Biota

Species-specific data are for TBT in biota are summarized below by tissue type. Scatter plots showing the distribution of TBT concentrations in select biota tissue collected from the Study Area are provided on Figures 5.6-14a-e. A box-whisker plot showing the distribution of TBT concentrations in whole body tissue samples collected of each species across the Study Area is provided on Figure 5.6-28.

5.6.14.1 TBT in Fish Tissue

As shown in Table 5.6-1, TBT was detected in all fish samples collected from the Study Area that were analyzed for this contaminant. Selected fish species were also collected from the Downstream Reach (Table 5.6-2) and above the Study Area (Table 5.6-4) for TBT analysis. Species-specific data are summarized below by tissue type.

Black Crappie

Black crappie samples collected from the Study Area were not analyzed for TBT.

Brown Bullhead

Brown bullhead samples collected from the Study Area and from locations above and from the Downstream Reach were not analyzed for TBT.

Carp

Six skin-on fillet composite samples of carp were collected within the Study Area and submitted for laboratory analysis of TBT. TBT was detected in five samples out of six, with detected concentrations ranging from 3.7 J to 11 J µg/kg (maximum concentration between RM 8 and 12; Map 5.6-3c).

Six whole body composite samples of carp based on combined fillet and body without fillet fractions were also submitted for laboratory analysis of TBT. TBT was detected in each sample, with concentrations ranging from 3.4 J to 8.6 µg/kg (maximum concentration between RM 8 and 12; Map 5.6-3c). Additionally, six carp body without fillet samples were collected from the Study Area. TBT was detected in each sample, with concentrations ranging from 4.3 J to 9.8 µg/kg (RM 8 to 11; Map 5.6-3c).

Nine composite carp samples were collected within the Downstream Reach (between RM 0 and 1; Map 5.6-3a) and submitted for analysis of TBT, which was detected in all nine samples. TBT concentrations for the skin-on fillet composite samples ranged from 2.6 J to 7 µg/kg. TBT concentrations for three body without fillet composite samples ranged from 2.8 J to 8.4 µg/kg. TBT concentrations for three composite samples of combined fillet and body without fillet fractions ranged from 2.7 J to 7.5 µg/kg.

Chinook Salmon

Eight juvenile whole body Chinook salmon samples were collected within the Study Area and were composited for laboratory analysis of TBT. TBT was detected in each sample, with concentrations ranging from 1.3 J to 4.1 J µg/kg (maximum concentration between RM 6 and 7; Map 5.6-4b).

Three juvenile whole body composite samples were also collected from the Upriver Reach for TBT analysis. TBT was detected in each sample, with concentrations ranging from 0.37 J to 0.45 J µg/kg (maximum concentration between RM 17 and 18; Map 5.6-16).

Lamprey Ammocoetes and Macropthalmia

One juvenile (ammocoete) lamprey sample was collected from the Study Area for TBT analysis. TBT was detected at a concentration of 4.1 µg/kg (between RM 1 and 10; Map 5.6-8).

Largescale Sucker

Largescale sucker samples collected within the Study Area and from locations in the Downstream Reach and Upriver Reach were not analyzed for TBT.

Northern Pikeminnow

Northern pikeminnow samples collected within the Study Area and from locations in the Downstream Reach and Upriver Reach were not analyzed for TBT.

Peamouth

Peamouth samples collected within the Study Area and from locations in the Downstream Reach and Upriver Reach were not analyzed for TBT.

Sculpin

Sixteen whole body composite samples of sculpin were collected and submitted to the laboratory for TBT analysis. Twelve of these samples were collected from the Study Area. TBT was detected in four of the samples collected from the Study Area. Detected TBT concentrations ranged from 2.3 J to 4 J µg/kg (RM 4 to 8; Maps 5.6-11c-d).

Two whole body composites were collected from the Downstream Reach, with no detected TBT concentrations in both samples. Two whole body sculpin composites were also collected from the Downtown Reach for TBT analysis. TBT was detected in one of the samples at a concentration of 6.2 µg/kg (near RM 1.5; Map 5.6-11a).

Smallmouth Bass

Thirty-six smallmouth bass samples were collected and submitted to the laboratory for TBT analysis. All of these samples were collected from the Study Area and included 18 composites of body without fillet and 18 fillet without skin composites. In addition, concentrations were derived for 18 composites by calculating concentrations for fillet and body without fillet fractions.

TBT was only detected in four of the composite samples of combined fillet and body without fillet fractions and four fillet samples. Detected concentrations of these Study Area smallmouth bass samples, as presented on Maps 5.6-12a-b, ranged as follows:

- Fillet—0.48 J to 0.92 J µg/kg (maximum concentration between RM 3 and 5)
- Combined fillet and body without fillet fractions—0.78 J to 1.6 J µg/kg (maximum concentration between RM 3 and 5).

Sturgeon

Fifteen whole body sturgeon samples were collected from the Study Area and submitted to the laboratory for TBT analysis. As presented on Map 5.6-13b, TBT was detected in four of the samples. Detected TBT concentrations ranged from 0.61 J to 1.1 µg/kg (maximum concentration between RM 9 and 10).

5.6.14.2 TBT in Invertebrate Tissue

As shown in Table 5.6-5, TBT was detected in all invertebrate species and tissue types collected from the Study Area for which analysis was conducted. Selected invertebrate species were also collected from the Downstream Reach and from the Downtown and Upriver Reaches (Tables 5.6-6 and 5.6-7, respectively).

Clams (Resident)

All clam samples consisted of soft parts only (body without shell). Thirty-three composites of resident clams (non-depurated) were collected within the Study Area and submitted to the laboratory for TBT analysis. TBT was detected in 21 samples, with concentrations ranging from 2.5 to 530 µg/kg (RM 8 to 9; Map 5.6-5d). Two additional depurated samples were collected within the Study Area; however, TBT was not detected above laboratory reporting limits.

Three composite clam samples, one depurated and two not depurated, were collected from the Downstream Reach. TBT was detected in one non-depurated sample at a concentration of 4.7 µg/kg (Multnomah Channel; Map 5.6-5b). TBT was not detected above laboratory reporting limits for the depurated sample.

Three composite clam samples, one depurated and two not depurated, were also collected from the Downtown Reach. TBT was not detected in any of the samples.

Clams (Laboratory-Exposed)

Thirty-four additional clam results were generated by exposing laboratory-reared clams to Study Area sediments, followed by analysis of soft body parts for TBT. TBT was detected in nine of the samples, with concentrations ranging from 1.1 to 680 µg/kg (maximum concentration from sediments collected between RM 8 and 9; Map 5.6-6e).

One clam sample was analyzed by exposing laboratory-reared clams to Downstream Reach sediments, followed by analysis of soft body parts for TBT. TBT was not detected above laboratory reporting limits.

Crayfish

Five whole body crayfish composites were collected within the Study Area and submitted to the laboratory for TBT analysis. TBT was detected in three of the samples, with detected concentrations ranging from 0.56 J to 2.3 µg/kg (RM 6 to 7; Map 5.6-7c).

Two composite whole body crayfish samples were collected from the Downstream Reach. TBT was detected in one of these two samples at a concentration of 1.3 J µg/kg (near RM 1; Map 5.6-7a).

Two composite whole body crayfish samples were also collected from the Downtown Reach. TBT was detected in one of these two samples at a concentration of 1.6 µg/kg (near RM 12; Map 5.6-7d).

Epibenthic Invertebrates

Epibenthic invertebrates (mixed taxa) collected from the Study Area were not analyzed for TBT.

Laboratory-Exposed *Lumbriculus* Worms

Thirty-four results were generated by exposing laboratory-reared *Lumbriculus* worms to Study Area sediments, followed by analysis of whole body worms for TBT. TBT was detected in 14 samples, with detected concentrations in these laboratory-exposed samples ranging from 2.1 to 1,700 µg/kg (maximum concentration from sediments collected between RM 8 and 9; Map 5.6-14e).

One result was generated by exposing laboratory-reared *Lumbriculus* worms to Downstream Reach sediments, followed by analysis of whole body worms for TBT. TBT was detected at a concentration of 2.6 µg/kg (Multnomah Channel; Map 5.6-14b).

Mussels

Seven composites of resident mussels were collected within the Study Area and submitted to the laboratory for TBT analysis. TBT was detected in each sample, with concentrations ranging from 2.2 J to 16 J µg/kg (between RM 3 and 4; Map 5.6-9a).